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A gas turbine combustor test facility for fuel composition investigations

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THESIS

A GAS TURBINE COMBUSTOR TEST FACILITY FOR FUEL COMPOSITION INVESTIGATIONS

by

Robert William DuBeau

June 1983

Thesis Advisor: D. W. Netzer

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fuel additive evaluations to determine the resulting effects on soot production and consumption rates.

A Gas Turbine Combustor Test Facility for Fuel Composition Investigations

by

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Lieutenant Commander, United States Navy
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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

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June 1983

ABSTRACT

Construction, check-out/verification and initial tests of a full scale gas turbine combustor test facility were accomplished. Water cooled gas sampling and stagnation probes and a multiple wavelength light extinction measurement apparatus for determination of mean particulate size were evaluated. The facility will be used for subsequent fuel composition/fuel additive evaluations to determine the resulting effects on soot production and consumption rates.

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TABLE OF SYMBOLS AND ABBREVIATIONS

C_{m_c}	Combustor particulate mass concentration
C_{m_e}	Exhaust exit mass concentration
d_{32}	Volume-to-surface mean particle diameter (microns)
f	Fuel-to-air ratio; $\dot{m}_f/\dot{m}_e$
m	Complex refractive index
$\dot{m}_a$	Engine air mass flow rate (lbm/sec.)
$\dot{m}_f$	Fuel mass flow rate (lbm/sec.)
NO_x	Nitrogen oxide concentration
P_{air}	Pressure of air (psia)
P_c	Combustor internal pressure (psia)
ΔP_{fuel}	Differential fuel pressure (psia)
T_λ	Percent transmittance at wavelength Å
T_{air}	Combustor inlet temperature (°R)
T_{exit}	Combustor exhaust temperature at exit (°R)
$T_{t_{probe}}$	Gas stagnation temperature as measured by the probe (°R)
σ	Geometric standard deviation

ACKNOWLEDGMENTS

I would like to acknowledge the complete support and assistance of Dr. David Netzer, Professor of Aeronautics, without whose help and afterhours participation this project would not have been completed. Dr. Netzer's personality, technical knowledge, and mechanical ability could be easily used as the benchmark for the ideal graduate educator. A very sincere thank you also to Aerospace Engineering Technicians Mr. Robert Besel and Mr. Glenn Middleton whose help and assistance were greatly appreciated. Their consistent good humor, cooperation, and tolerance set an excellent example for all to emulate. I would like to especially dedicate my efforts on this project to my father who died during the final week of thesis research. Finally, a special thanks to my wife, Kathy, for her total support during our tour at the Naval Postgraduate School.

I. INTRODUCTION

The maintenance requirements of high performance turbojet/turbofan engines require the Navy to utilize jet engine test cells at shore based jet engine rework facilities. The facilities provide a static, controlled environment in which to conduct engine overhaul evaluations prior to reinstallation aboard aircraft. A significant gain in operational safety is achieved by the Navy's policy of full engine performance testing prior to returning it for service use.

The Navy's use of jet engine test cells often must satisfy federal regulations issued by the Environmental Protection Agency (EPA). In addition, these minimum national pollution control guidelines are frequently made more stringent by local governmental regulations and controls. The inability to meet the local pollution standards imposed by the San Diego and Bay Area Pollution Control Districts has resulted in lawsuits against the Navy [Ref. 1]. Currently, the pollutants produced by engines while operating in shore based test cells must satisfy local requirements. Once installed in military aircraft, however, these engines are not required to conform to local regulations. Thus, the primary concern is the test cell exhaust emissions which originate during engine post-overhaul testing. Technical

evaluations of engine performance require test conditions similar to those found in actual flight environments. Thus, it is necessary to meet both federal and local environmental regulations while still ensuring acceptable test conditions.

The quantity and type of exhaust emissions depends upon the engine type (combustor geometry, fuel injectors, etc.), the fuel composition, and test cell design. Technology has not yet advanced to the point of being able to produce pollution-free, high-performance engines while still meeting demanding mission requirements and specifications. Therefore, another means of reducing pollutant levels is necessary. Extensive test cell modifications are often cost prohibitive; therefore, various research efforts have been initiated to evaluate the effectiveness of fuel additives as a relatively inexpensive solution to this problem.

Recently the Air Force Aero Propulsion Laboratory has conducted research into the effects of broad variations in fuel properties on the main combustor and turbine systems of various turbojet and turbofan engines [Ref. 5]. The study concerned itself predominantly with the correlation of fuel chemical composition and physical properties on engine operability and durability. Spin-off results have indicated an additional correlation to exhaust gas emissions. Fuel hydrogen content was found to be the best indication of fuel quality as it relates to combustion properties, and was used to correlate smoke and NO_x emissions.

Research at the Naval Postgraduate School has been directed at evaluating smoke suppressant fuel additives. As summarized in Bramer's research [Ref. 2], Hewlett [Ref. 6] initiated the program with design and construction of a one eighth scale turbojet test cell at the school's Aeronautics Laboratory. Charest [Ref. 7] designed, constructed, and evaluated the use of a ramjet type dump combustor for simulation of the turbojet combustion process. In another research program, Hewett [Ref. 8] utilized light extinction measurements to determine the effects of fuel composition and bypass ratio on the concentration and size of unburned carbon within a solid fuel ramjet. Darnell [Ref. 9] adapted the latter technique to make measurements of particle sizes and concentrations in the sub-scale test cell. His efforts were partially successful and resulted in recommendations for improvements in the experimental techniques in order to improve the quality of collected data. Thornburg [Ref. 3] incorporated these suggestions and used the improved facility for experiments to investigate the overall effectiveness of several smoke suppressant fuel additives. Bramer [Ref. 2] utilized the existing test apparatus to conduct extensive tests using six fuel additives. Exhaust particle sizes and mass concentrations were determined at the engine and stack exhausts.

These previous experiments have documented the effects of various fuel additives upon contaminate particle size and density. Additionally, measurements of nitrous oxide (NO_x) gas were made. Test results are contained in the previous research reports [Refs. 2, 3, 6, 7, and 9]. However, very little of the data could be used to further the understanding of how and where the additives work. For this reason the test apparatus was redesigned both to more nearly simulate the actual gas turbine combustion process and to provide improved diagnostic methods. The new design incorporated a full size engine combustor (T63) which could be operated at more realistic pressure levels. Two opposed viewpoints were installed in the combustion chamber walls to permit continued use of the collimated light detector measurements for determination of the effects of fuel compositions and additives on the concentration and size of unburned soot within the combustor. Provisions were also made for internal probe measurements of total pressure, temperature and gas composition.

The primary objective of the present investigation was to construct and check-out the new test facility. If the facility could be completely installed and successfully operated, it was also desired to initiate an investigation to determine the effects of varying JP composition on soot production.

II. EXPERIMENTAL APPARATUS

A. GENERAL DESCRIPTION

The primary test article used in this experiment consisted of a gas turbine combustor (T63) mounted externally on a static test stand (Fig. 1). A combustor expanded view and photograph showing the sample probe in position with the aft-closure section are presented as Figs. 2 and 3. Other subsystem components included a fuel supply system, a high pressure air supply system, and an instrumentation package. A brief subsystem description is presented below.

Combustor air was supplied from storage tanks which were pumped to approximately 3000 psi using a Joy Manufacturing Company, Model 415HEP3M51 reciprocating compressor (Figs. 4 and 5, respectively). In order to closely simulate typical combustor inlet conditions for temperature and pressure, a vitiated air heater (Figs. 6, 7 and 8) could be used. The heater is based on a sudden expansion, can-type combustor, where part of the air reacts with the fuel (ethylene) to produce nearly stoichiometric temperatures, and dilution air is used to reduce the air temperature to the desired value. Make-up oxygen is injected downstream of the heater to replace the oxygen consumed in the combustion process.

The exhaust gases produced in the T63 combustor exit through the turbine nozzles into a locally fabricated aft

chamber which initially incorporated a variable area exhaust nozzle. The variable exhaust area was designed to enable adjustment of combustion back pressure during testing.

The test apparatus was designed to be operated from a remote control-room. However, when the gas sampling probe was used, the related apparatus were operated from behind a protective shield within the test cell.

B. FUEL SUPPLY SYSTEM

The fuel supply system (Figs. 9, 10, 11, and 12) consisted of a fuel supply tank, an electro-mechanical remote control panel, and two Eldex, Model E, precision metering pumps to provide desired fuel additive levels. Fuel flow rate to the combustor was controlled using fuel tank pressure and measured using the pressure drop across the fuel poppet valve.

C. INSTRUMENTATION

Test instrumentation consisted of the following:

(1) A combustion product sampling probe (Figs. 13 and 14): The probe design was based on the work of Samuelson [Ref. 10]. It was water cooled (Fig. 15) and incorporated ports for determination of isokinetic sampling conditions, a nitrogen quench port, a gas sampling port, and the primary particulate sampling line. The probe could be translated along the combustor centerline over the entire length of

the combustor. The particulate sampling line was heated and connected to a collection apparatus located within an oven.

(2) A particulate collection apparatus (Figs. 16 and 17): This apparatus permitted the timed collection of particulate matter from the sampling probe. The probe gases were by-passed until isokinetic conditions were established. The gases were then directed through two series mounted Swin-Lok Membrane Holders with 8.0 and 0.2 micron filters, respectively. Particulate size could be analyzed by use of a Scanning Electron Microscope (SEM). The sampling board was mounted inside a portable laboratory oven heated to 150° F to prevent water cendensation within the sample line and the associated particulate agglomeration.

(3) A stagnation temperature probe (Fig. 18): This probe was also water cooled and could be translated along the combustor centerline from the primary reaction zone to the combustor exit. In this investigation the probe was located in the full aft position.

(4) An apparatus for transmission measurements (Figs. 1, 19, and 20): Combustor exit and motor exhaust mean particle sizes were determined using a three frequency light transmission technique [Ref. 11]. Two opposed viewports were constructed in the liner near the aft end of the combustor. Another set of detectors were located at the combustor exit.

The equations used to calculate d_{32} from the measured transmittance data are presented in Refs. 2, 3, and 8. Samples collected using the combustor probe were used by Krug [Ref. 12] to verify the light transmission technique.

(5) Data acquisition: Data acquisition of test temperatures and pressures were recorded manually or on a Visicorder (Fig. 21). Light transmission data were recorded on strip chart recorders (Fig. 22). In the future all data will be obtained using the existing Hewlett-Packard data acquisition system.

(6) An exhaust opacity measurement device: A Leads and Northrop Model 6597 transmissometer (Figs. 23 and 24) was utilized to measure engine exhaust gas opacity. The data were recorded on a strip chart recorder.

(7) A nitrogen oxide analyzer: A Monitor Labs, Model 8440E, Nitrogen Oxide analyzer could be used to examine sampled exhaust gas to determine the effect of fuel additives on NO_x production.

III. EXPERIMENTAL PROCEDURE

A. GENERAL

Test procedures were formulated which attempted to permit a consistent operating environment in which to conduct T63 combustor tests. Pre-run calibrations and a strict adherence to predetermined warm up times were followed to achieve repetitive results. Initially, preliminary test runs were conducted at minimal pressure and temperature levels to provide an adequate experimental build-up which ensured personnel and equipment operational safety margins. The following outlined method of test summarizes the actual procedures following during test execution.

B. WARM UP/CALIBRATION

All electrical components and instrumentation were warmed up for 30 minutes prior to commencement of testing. Calibration of all pressure transducers (P_{air}, ΔP_{fuel}, and P_c) were performed. The transmissometers were checked and zeroed. Once measurement equipment outputs were reliable and correct, air flow rates and vitiated heater requirements could be determined. The optical light detector system was checked by measuring the maximum detector outputs and comparing them to output data taken when the system was first installed and aligned.

C. SET POINT/DATA ACQUISITION

Air flow rates and temperature were adjusted to obtain the following nominal values:

Combustor primary air----------------2.80 (lbm/sec)

Combustor exit temperature-----------1,150.0 (°F)

With air flowing through the motor, a final check of the measurement equipment was made. New zeros and one hundred percent readings were taken as necessary. After final adjustments were complete, the fuel tank pressure was adjusted to obtain the desired fuel flow rate.

Once the desired combustor exhaust temperature was achieved through manipulation of the fuel flow rate, and steady state outputs were obtained, data were taken. Following the "JP-4 only" data recording, the fuel additive pumps could be activated. The light transmittances were continuously recorded on strip chart recorders.

D. SHUT DOWN/RECALIBRATION

Following completion of data collection, the motor was shut down by securing primary fuel to the combustor. Post-run zeros and one hundred percent points were marked on the strip chart recordings to ensure that alignment of the optical measuring equipment had not changed.

IV. DATA REDUCTION

A. GENERAL

Experimental data reduction consisted primarily of the determination of opacity and mean particulate size from the recorded values of transmittance. A summary of the data reduction techniques utilized, as presented in Ref. 2, are provided below for report clarity.

B. OPACITY

Opacity of the combustor exhaust gases was measured directly with a white light source transmissometer. As defined by the EPA, opacity is the degree to which emissions reduce the transmission of light and obscure the view of an object in the background (Ref. 13). Opacity is related to the transmission of light by:

$$\% \text{ OPACITY} = 100\% - \text{TRANSMITTANCE.}$$

C. PARTICULATE SIZE

Mean exhaust particle sizes can be determined within the combustor and at the exit using Bouguer's Daw [Ref. 11] for the transmission of light through a cloud of uniform particles:

$$T = \exp(-QAnL) = \exp[-(3QC_m L/2\rho d)] \tag{1}$$

where (T) is the fraction of light transmitted, (Q) is the

dimensionless extinction coefficient, (A) is the cross sectional area of a particle, (n) is the number concentration of particles, (L) is the path length the light beam traverses, (C_m) is the mass concentration of particles, (ρ) is the density of an individual particle, and (d) is the particle diameter.

Using Mie light scattering theory, the dimensionless extinction coefficient (Q) can be calculated as a function of particle size for a specified wavelength of light, complex refractive index of the particle, and standard deviation of the particle size distribution.

Dobbins [Ref. 14] revised Bouguer's transmission law to allow for a distribution of particle sizes:

$$T = \exp[-(3\bar{Q}C_m L/2\rho d_{32})] \tag{2}$$

where ($\bar{Q}$)is an average extinction coefficient and (d_{32}) is the volume-to-surface mean particle diameter. Taking the natural logarithm of equation (3):

$$\ln[T] = \bar{Q}[-3C_m L/2\rho d_{32}] \tag{3}$$

For a specific wavelength of light, equation (3) can be written:

$$\ln[T_\lambda] = \bar{Q}_\lambda[-3C_m L/2\rho d_{32}]. \tag{4}$$

Assuming C_m, L, ρ, and d_{32} remain constant, the ratio of the

natural logs of the transmittances for two wavelengths of light is:

$$\frac{\ln[T_{\lambda_1}]}{\ln[T_{\lambda_1}]} = \frac{\overline{Q}_{\lambda_1}}{\overline{Q}_{\lambda_2}} \tag{5}$$

A Mie scattering computer program, provided by K. L. Cashdollar of the Pittsburgh Mining and Safety Research Center, Bureau of Mines, could be used to produce calculations of $\overline{Q}_\lambda$ and $\overline{Q}_\lambda$ ratios as a function of d_{32}. The following inputs to that program were used in this investigation:

Complex Refractive Index of Particles ($m = 1.95 - .66i$), ($m = 1.80 - .30i$), and ($m = 1.60 - .60i$).
Refractive Index of Surrounding Medium (1.0 for air).
Standard Deviation of the Distribution ($\sigma = 1.5, 2.0$).
Three Wavelengths of Light (4500 Å, 6500 Å, 10140 Å) at the exhaust and (5145 Å, 6500 Å, 10140 Å) within the combustor.

Transmissivity was determined by comparing the ratios of photodiode outputs with and without exhaust particles present (i.e., combustor on and off, respectively). D_{32} and $\overline{Q}_\lambda$ could be obtained from the output of Cashdollar's program using the log ratios of transmissivity of the three wavelengths of light measured within the combustor and at the exit. Using three transmittance ratios provides three

values for d_{32}. If all three d_{32} values are not nearly identical, then the complex refractive index and/or standard deviation chosen are not correct [Ref. 11]. Several values of m (complex refractive index) and σ (standard deviation) were used in this investigation. Once $\overline{Q}_\lambda$, d_{32}, and T_λ are known, mass concentration can be calculated with the following rearrangement of equation (4):

$$C_m = -\frac{2}{3}\left[\frac{\rho d_{32}}{\overline{Q}_\lambda L}\right]\ln T_\lambda \quad . \tag{6}$$

V. RESULTS AND DISCUSSION

A. INTRODUCTION

Construction of the gas turbine test facility began in January 1983 with the installation of the T63 combustor static test stand and related support apparatus. Significant modifications to existing test cell equipment were made to enable testing at representative fuel and air mass flow rates and temperatures. The vitiated air heater system (Fig. 6) was modified and tested, but not utilized during this investigation. It successfully provided a source of heated upstream air to the combustor at the nominal 2.8 lbm/sec mass flow rate and temperatures ranging from 200 °F to 500 °F.

The existing nitorgen pressurized fuel supply system (Fig. 9) was also modified to provide for remote operation from the control room. Nominal JP flow rates for the T63 combustor were between 0.035 and 0.04 lbm/sec. The fuel additive metering pumps (Fig. 12), used during previous research, were installed but were not utilized during this investigation.

Initial facility check-out/verification was conducted using a commercially procured JP-4 fuel. Two additional tests were completed using a Naval Air Propulsion Center (NAPC) fuel, NAPC-9. NAPC-9 and the other fuel compositions

to be evaluated in future investigations are presented in Table I. The data collected during this investigation are summarized in Tables II and III.

B. OPACITY EVALUATION

The output voltage from the exhaust opacity transmissometer (Fig. 23) was recorded on a strip chart recorder during facility testing. Opacity data ranged from 6.0 to 7.5 percent for combustor exit temperatures of 1032 to 1223 °F. The limited testing during this initial investigation was not adequate to develop a relationship between combustor exhaust temperature and opacity. However, the exhaust opacity was quite low with little variation for an approximately 200 °F variation in combustor exit temperature/fuel-air ratio.

C. PARTICULATE COLLECTION

The particulate collection apparatus (Figs. 16 and 17) was used in conjunction with the sampling probe (Figs. 13 and 14) to collect particulate samples from within the combustor. The device, based on the design presented in Ref. 10, was designed to enable collection of a particulate sample at any location along the combustor centerline (Fig. 2). In this investigation samples were collected only at the combustor exit. A sample line, heated to approximately 140 °F and oven (150 °F), as illustrated in

Fig. 16, were required to prevent water condensation in the probe/filter network. A test conducted without the heated line and oven resulted in excessive water and particulate accumulations on the filter elements. Heated water for the probe and N_2 dilution (as discussed in Ref. 10) will be used in future tests in an attempt to further improve the ability of the probe to collect particulates which are representative of those that actually exist within the combustor.

D. LIGHT EXTINCTION DATA

The three frequency light detection technique previously discussed (Figs. 19 and 20) was used in an attempt to obtain mean particle size data within the combustor and at the exhaust exit. Test data are presented in Tables II and III. Measurements were made within the combustor, but significant radiation in the IR and at 4500 Å resulted in data being obtained only at two wavelengths which were too narrowly separated in wavelength. Future tests will employ three more widely spaced filters which are not located at any of the dominant combustor radiation frequencies. At the exhaust exit, no useful data were obtainable due to the effects of very low opacity. A detailed discussion of these test results is contained in Ref. 12.

E. TEMPERATURE MEASUREMENTS

The water cooled stagnation temperature probe (Fig. 18) was placed at the exit of the combustor on the combustor centerline. The combustor exhaust occurs at its outer diameter. This apparently results in a significantly lower temperature at the aft end of the motor centerline. Typically, this temperature was 600 °F lower than the temperature measured in the exhaust ducting. Another thermocouple was located within the exhaust ducting. Data were recorded on a strip chart recorder, which enabled real time operator assessment of actual operating temperatures and provided a means for determining when steady state conditions were established. The stagnation temperature probe appeared to operate satisfactorily at the aft position. In subsequent investigations it will be used to determine stagnation temperatures at various locations along the engine axis.

F. PRIMARY FUEL CONTROL

The fuel pressurization system (Fig. 9) was used as the primary means to regulate combustor exhaust temperature through variation in the fuel/air ratio. Initial tests indicated that the pressure regulators which were used were not capable of providing fine control of the fuel tank pressure. This resulted in sporadic and unsteady combustor operations. Steady state conditions of 20-32 seconds could be maintained from which previously discussed test data

were obtained. Valve overhaul and the addition of an interlocking/bleed set pressure line corrected this problem.

VI. CONCLUSIONS AND RECOMMENDATIONS

During the gas turbine test facility initial check-out/verification, two jet fuels (commercial JP-4 and NAPC-9) were used in preliminary tests to verify system capability for determining combustor exhaust opacity, mean particle diameters within the combustor and at the exhaust exit, and combustor internal/exit temperatures.

Exhaust opacity data ranged from 6.0 to 7.5 percent for combustor exit temperatures of 1032 to 1223 °F. This exhaust opacity was quite low with little variation with significant variations in combustor exit temperature/fuel-air ratio.

The particulate collection apparatus, along with the sampling probe, provided acceptable particle samples from within the combustor. It is recommended that heated cooling water and an N_2 quench be incorporated to reduce water condensation/particulate agglomeration within the collection system.

The three frequency light detection technique enabled some measurements within the combustor, but significant radiation in the IR resulted in data being obtained only at two wavelengths which were too closely spaced. Future tests should employ three more widely spaced filters which are not located at any of the dominant combustor radiation frequencies. No useful data were obtainable at the exhaust exit due to the very low opacity.

The stagnation temperature probe appeared to operate satisfactorily at the aft end of the combustor.

Initial tests of the fuel pressurization system indicated that the pressure regulators which were used were not capable of providing fine control of the fuel tank pressure. This resulted in sporadic and unsteady motor operation. Valve overhaul and the addition of an interlocking/bleed set pressure line corrected this problem.

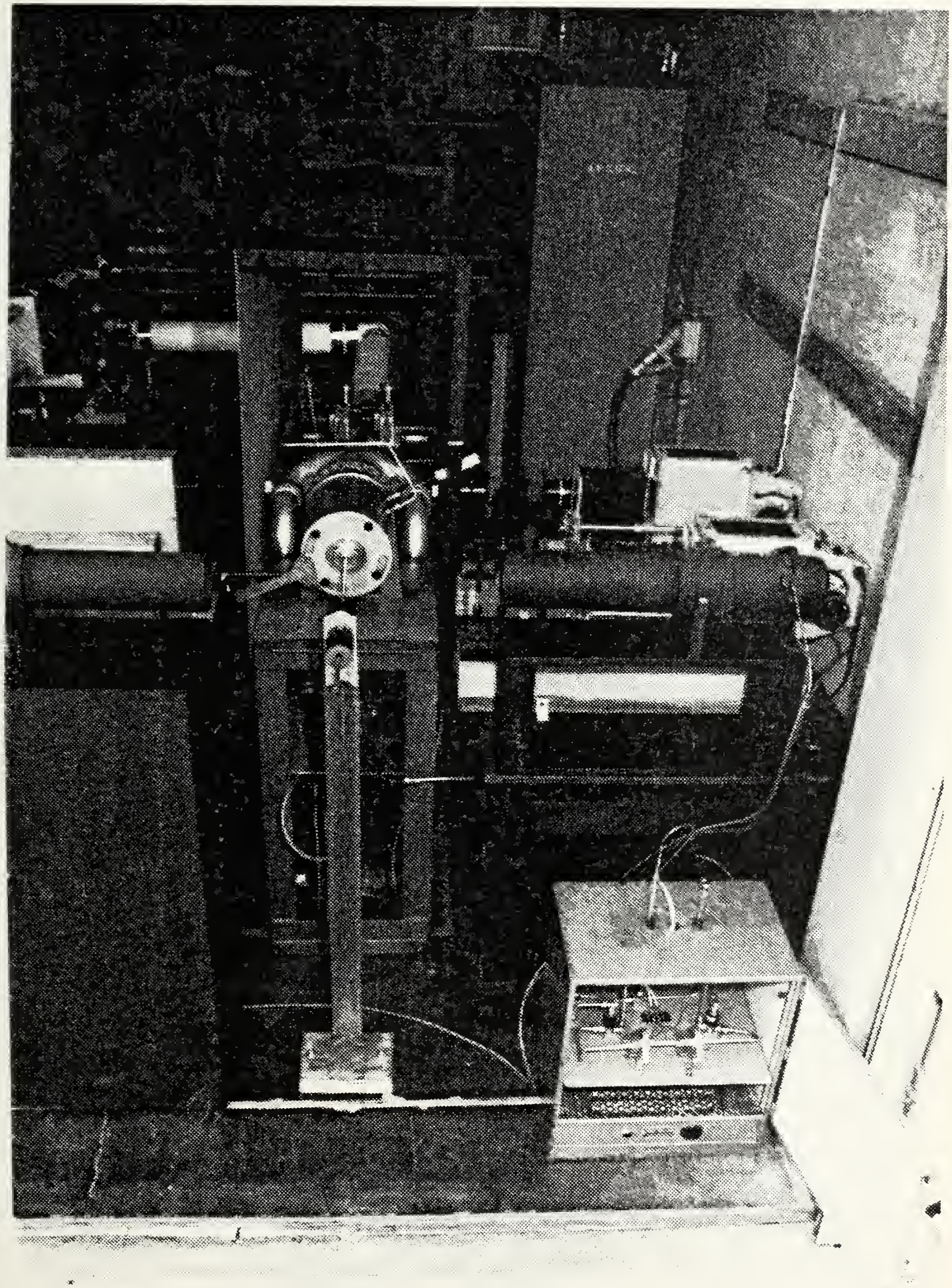

Figure 1. Combustor Test Facility.

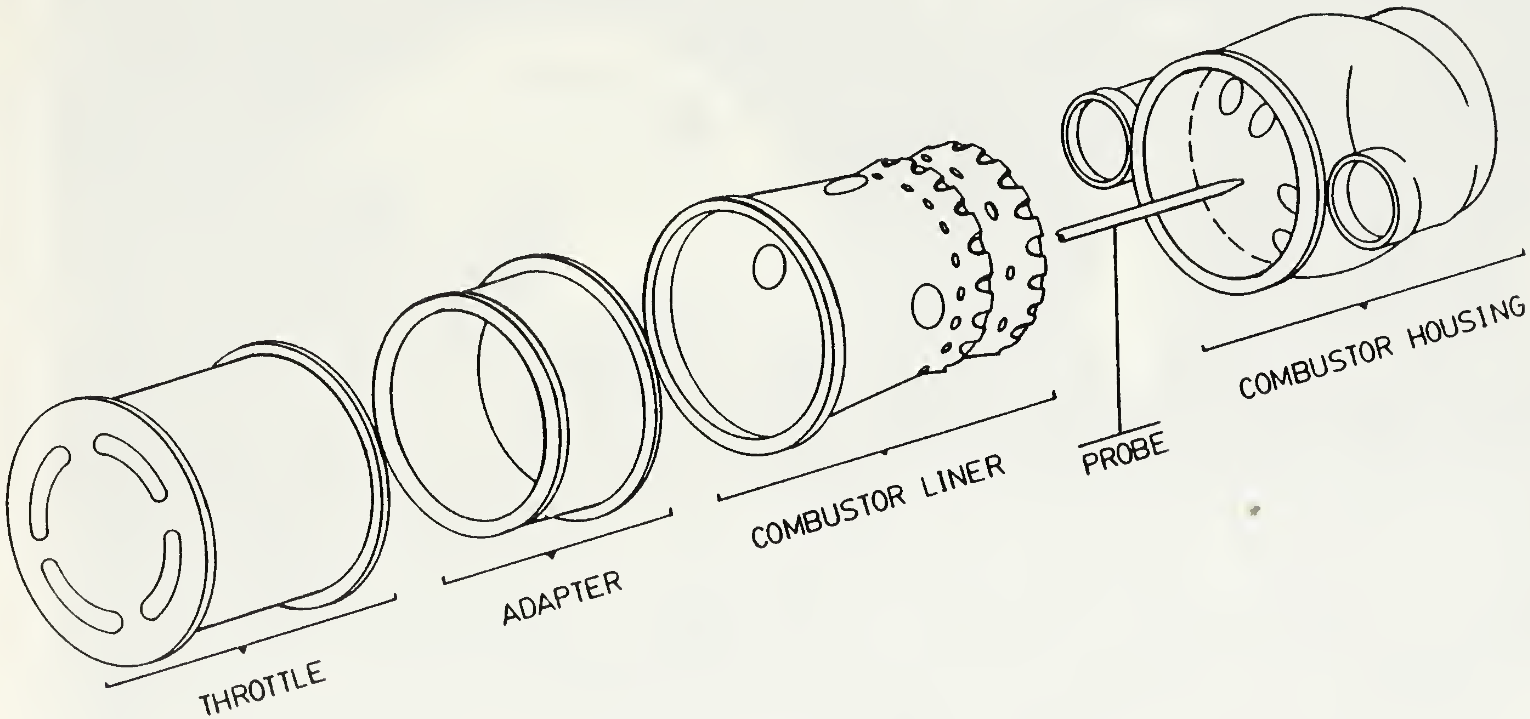

Figure 2. Combustor, Expanded View Diagram

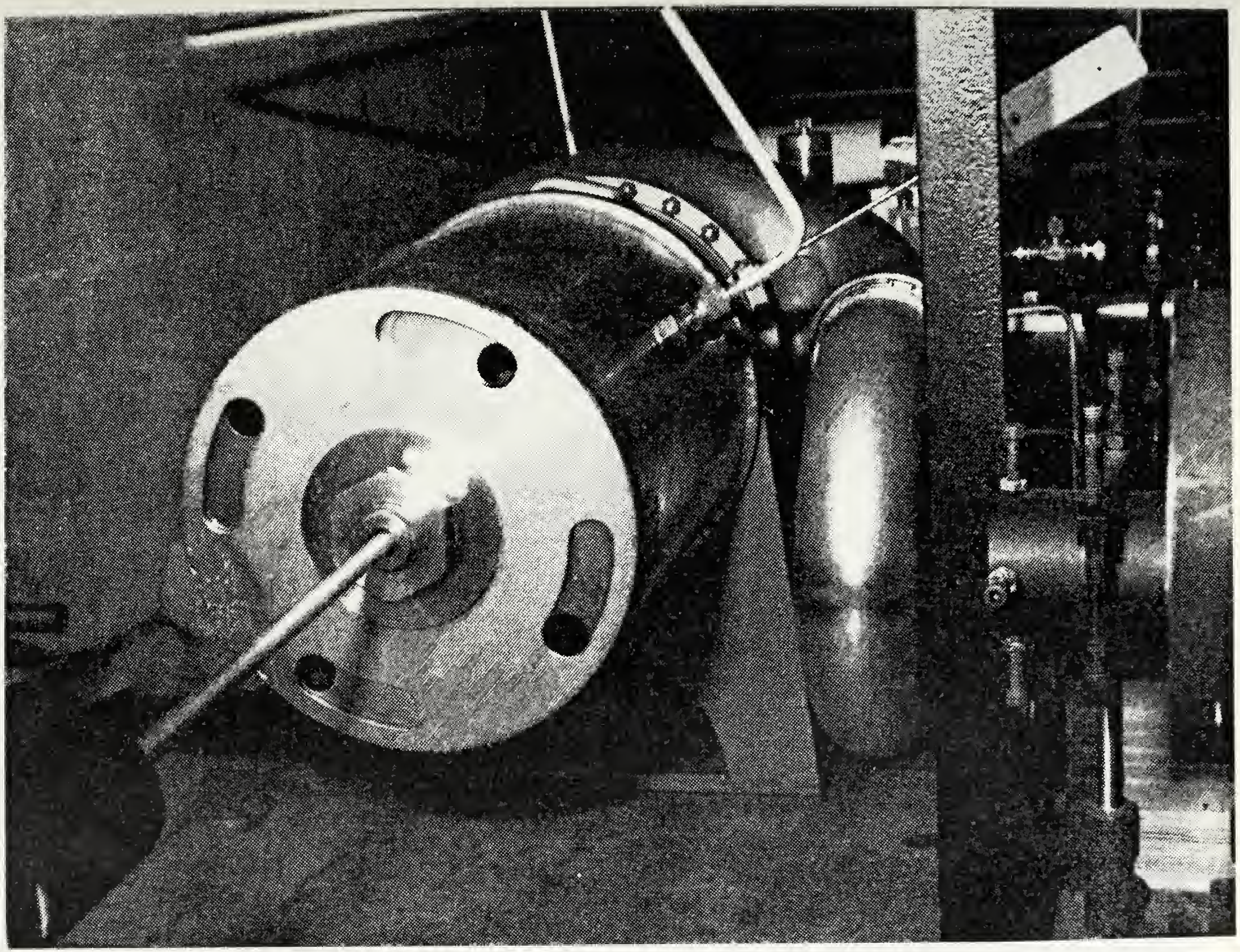

Figure 3. Combustor, Aft View.

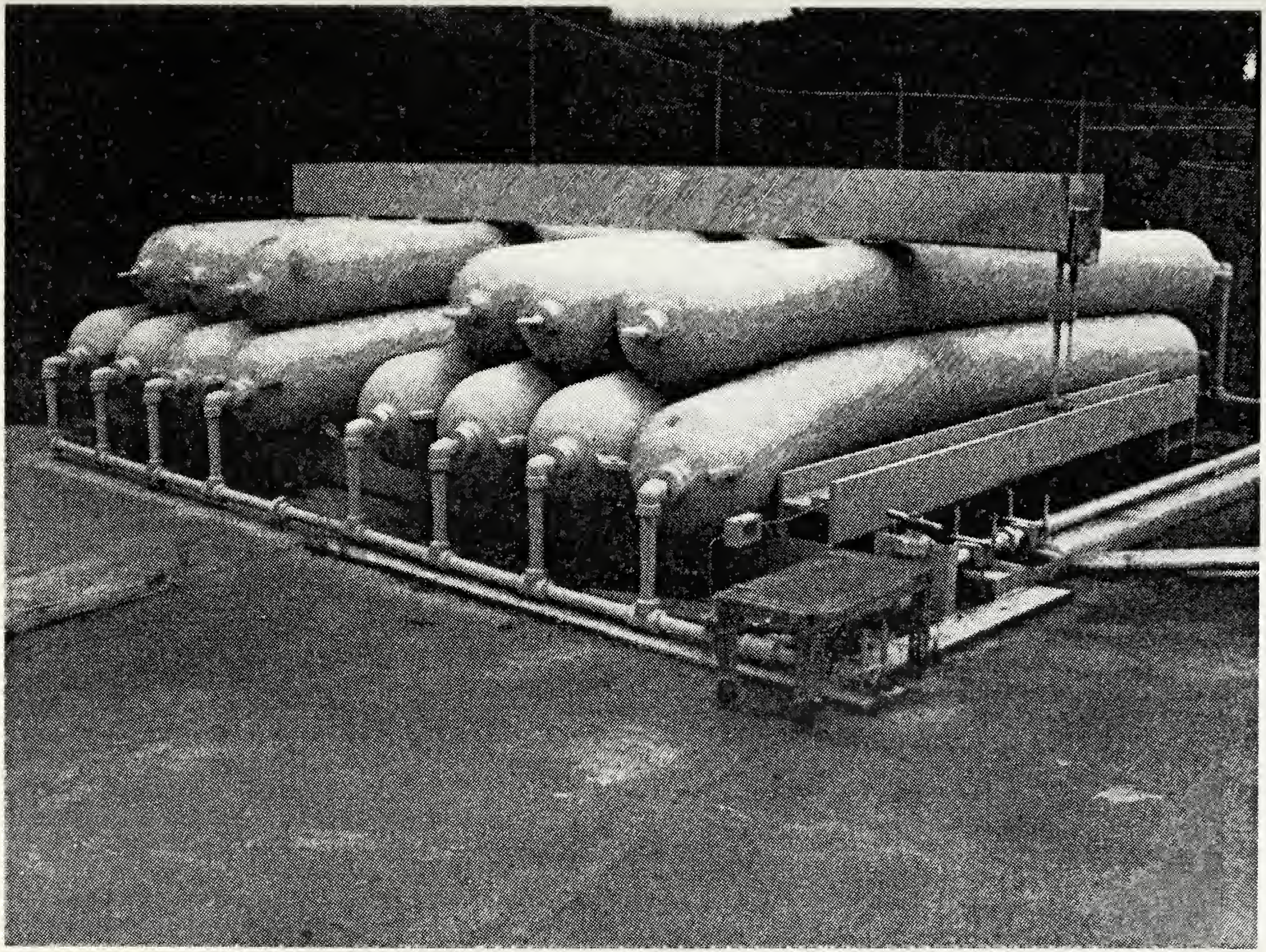

Figure 4. Air Storage Tanks.

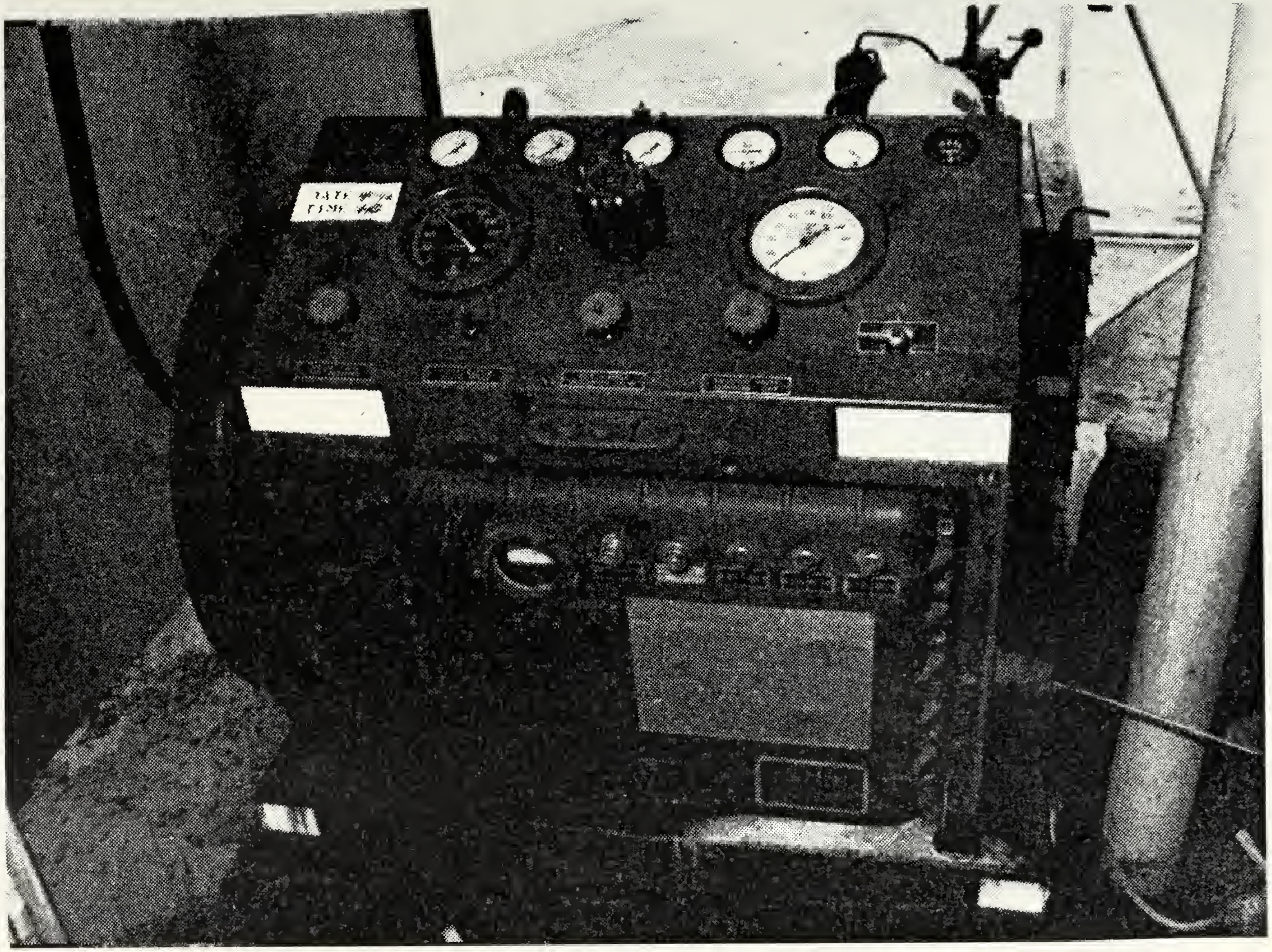

Figure 5. High Pressure Air Compressor.

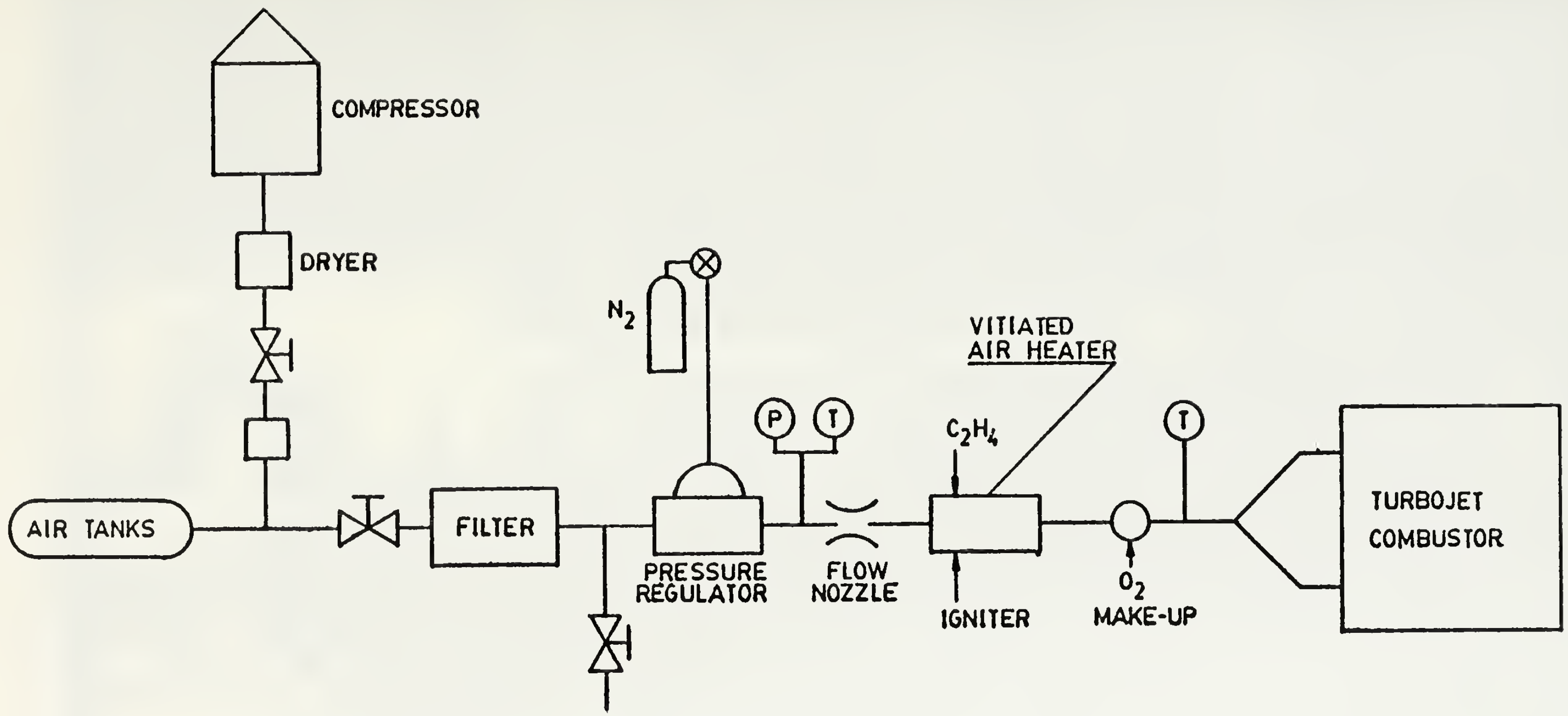

Figure 6. Vitiated Air Heater Diagram.

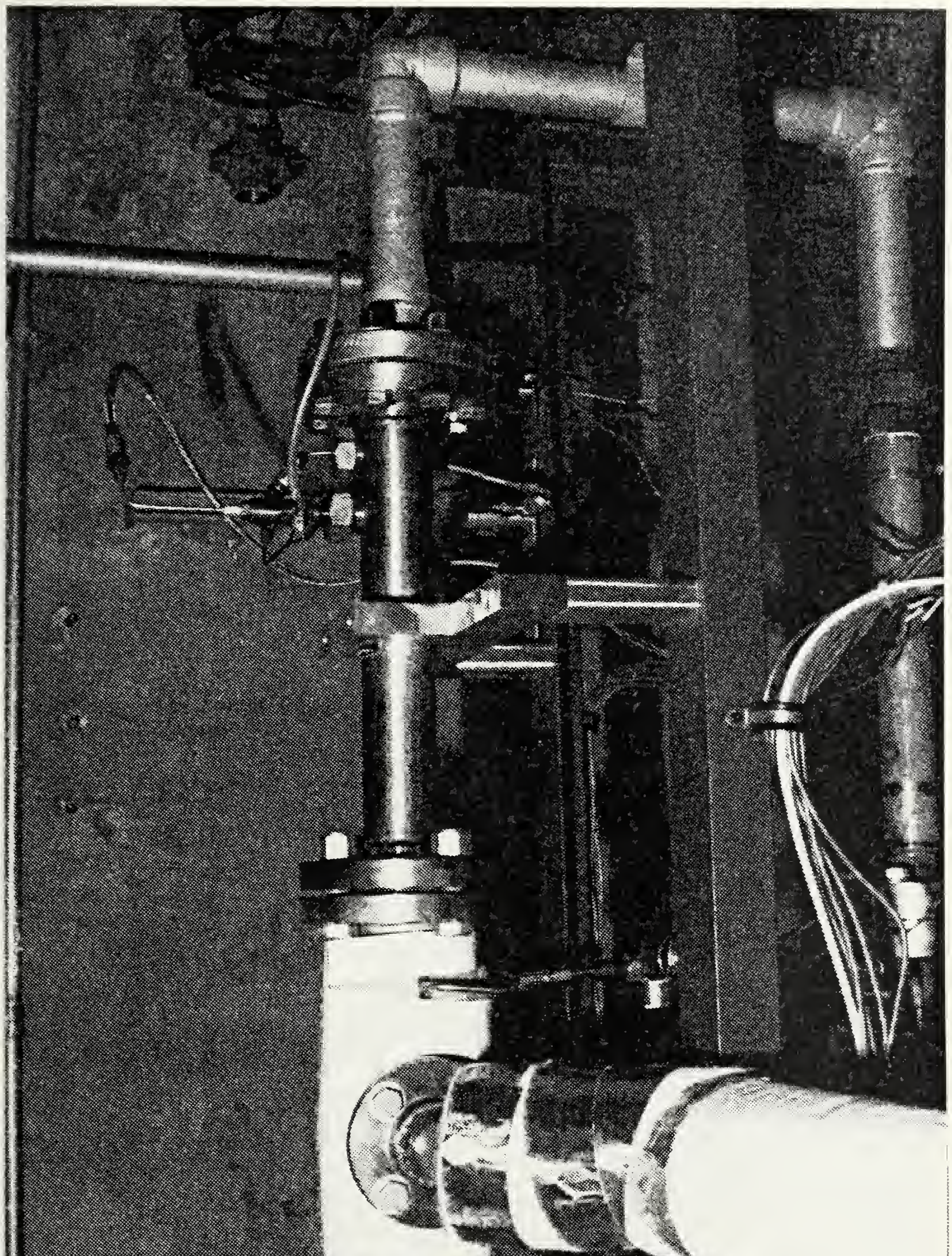

Figure 7. Photograph of a Vitiated Air Heater

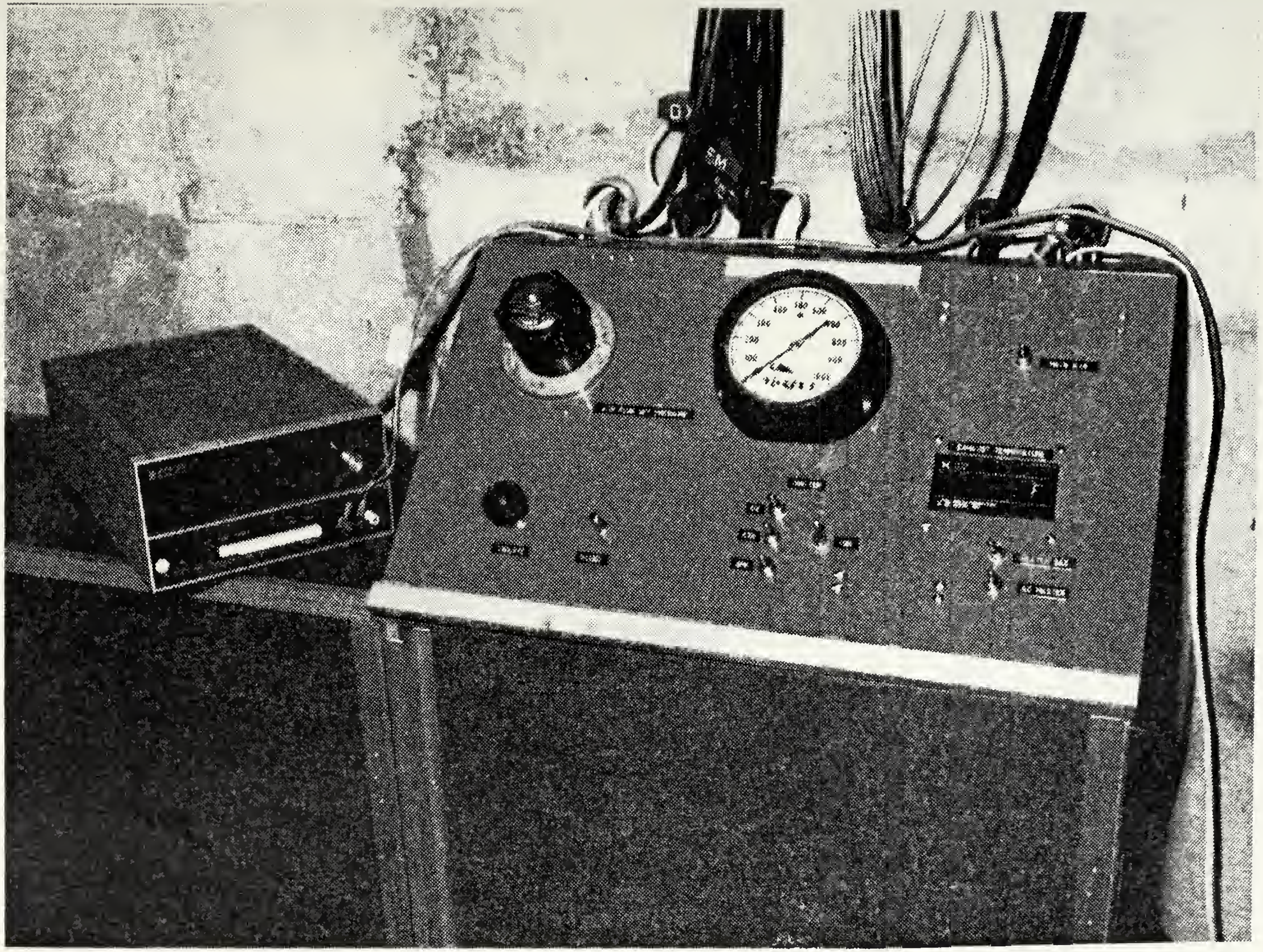

Figure 8. Vitiated Air Heater Control Panel.

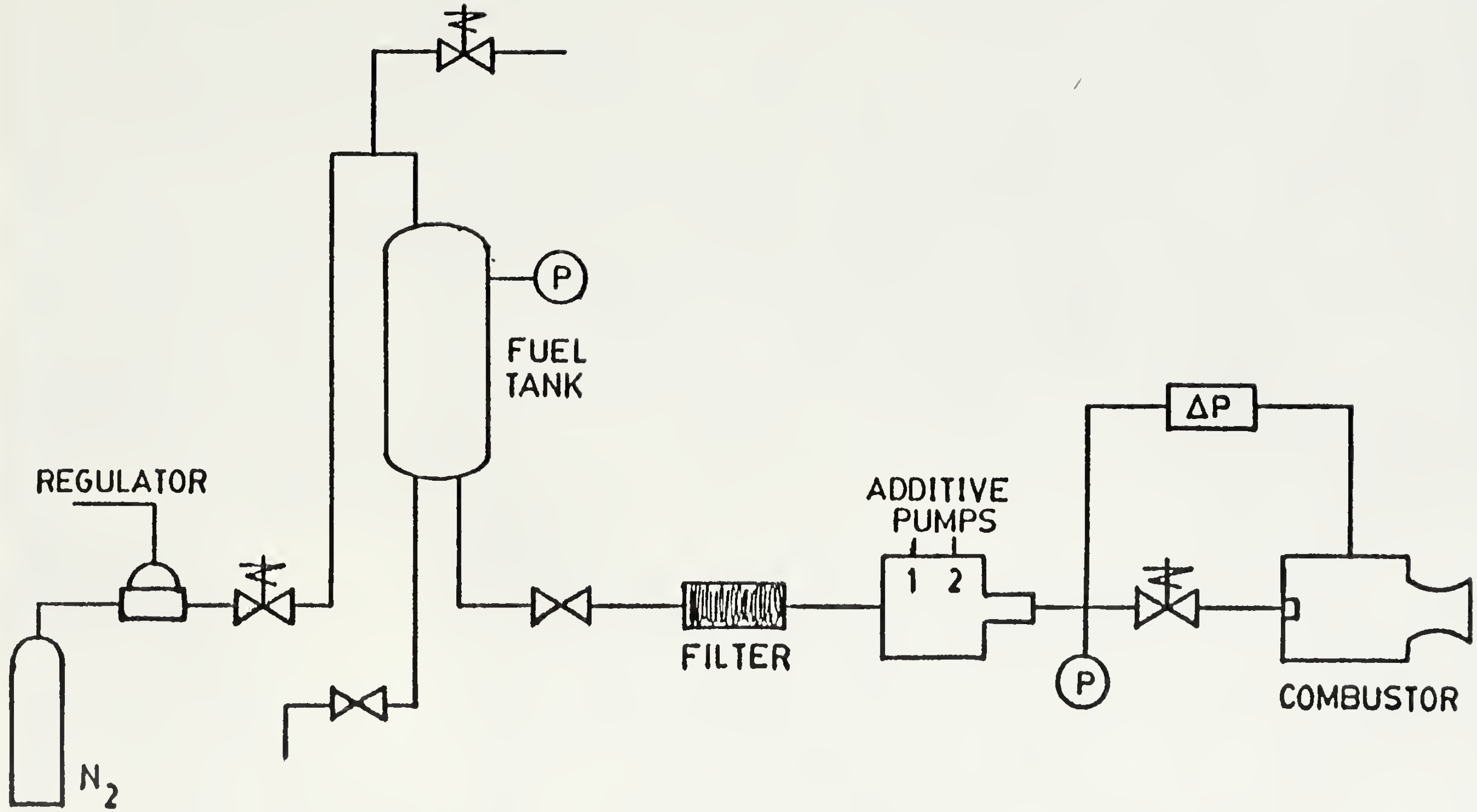

Figure 9. Fuel Supply System Diagram.

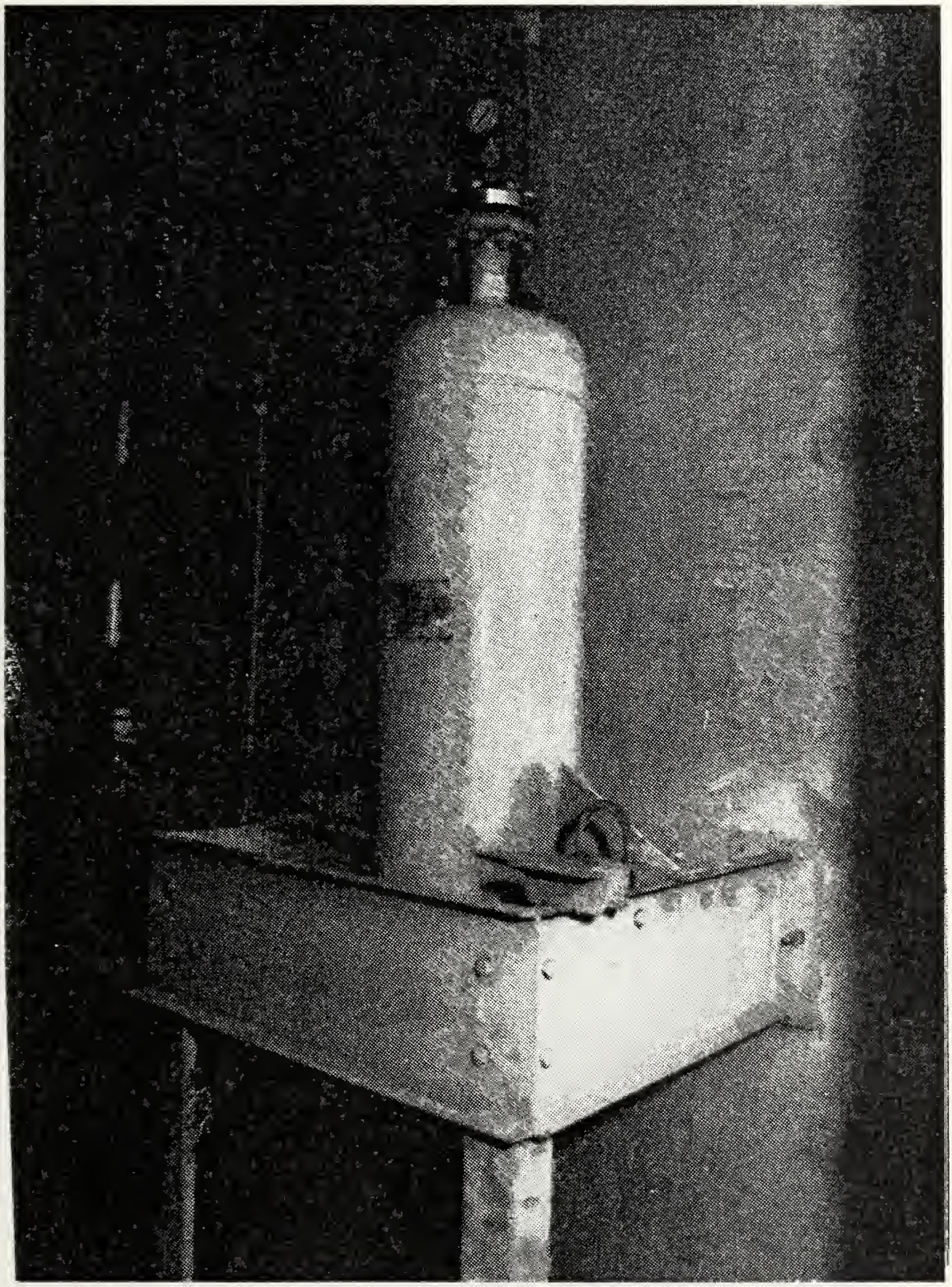

Figure 10. Fuel Supply Tank.

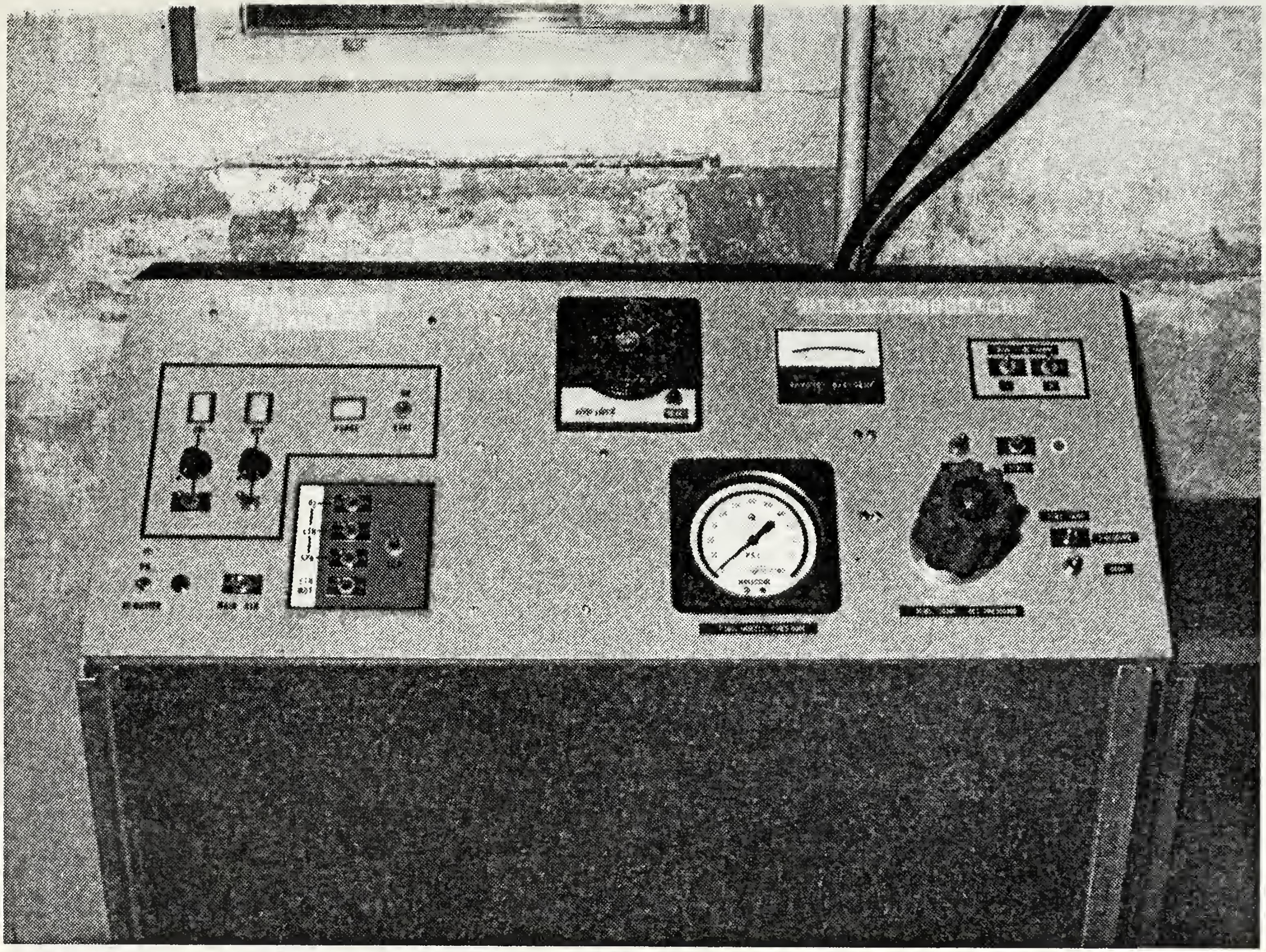

Figure 11. Fuel/Air Control Panel.

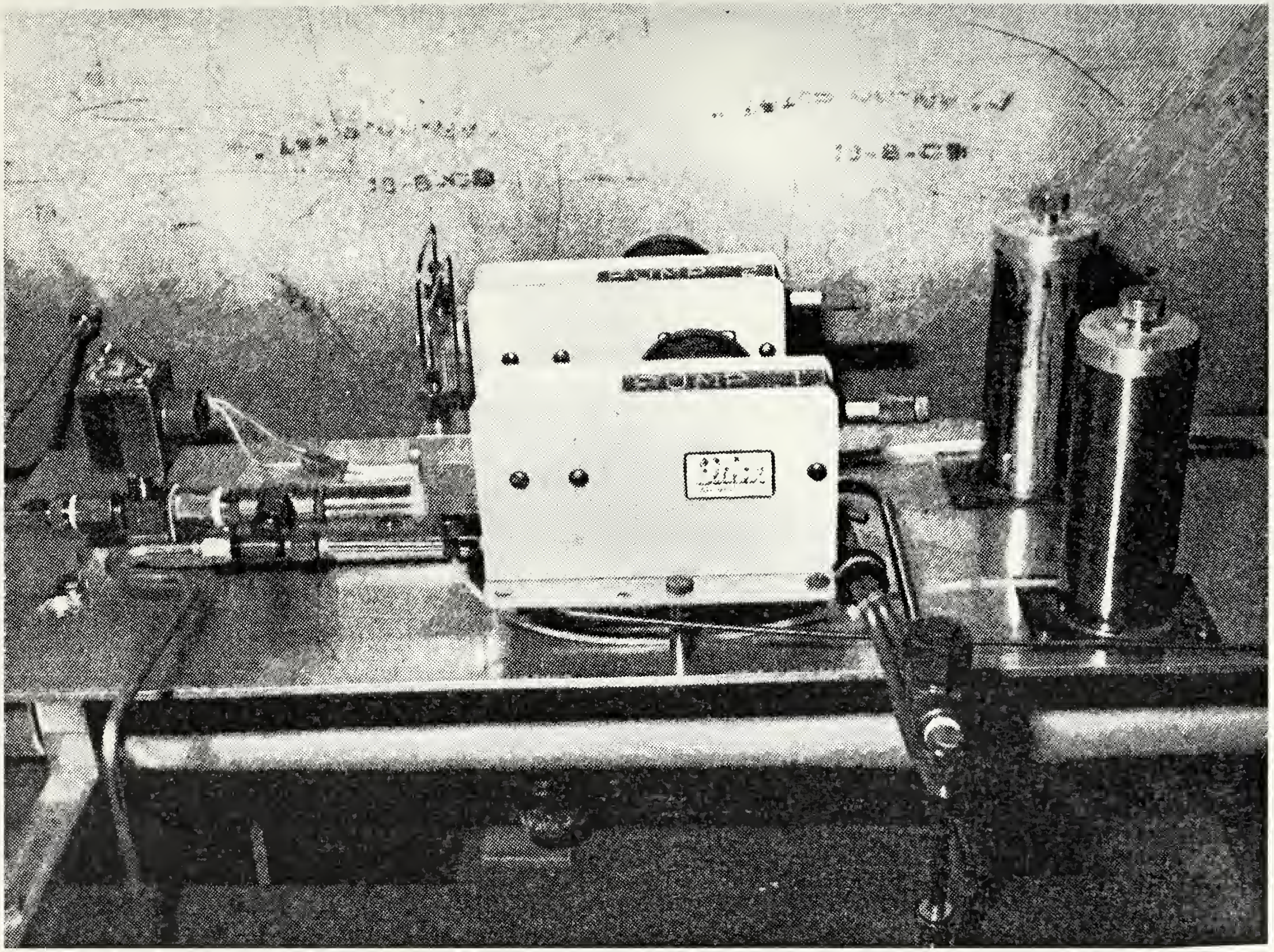

Figure 12. Fuel Additive Metering Pumps.

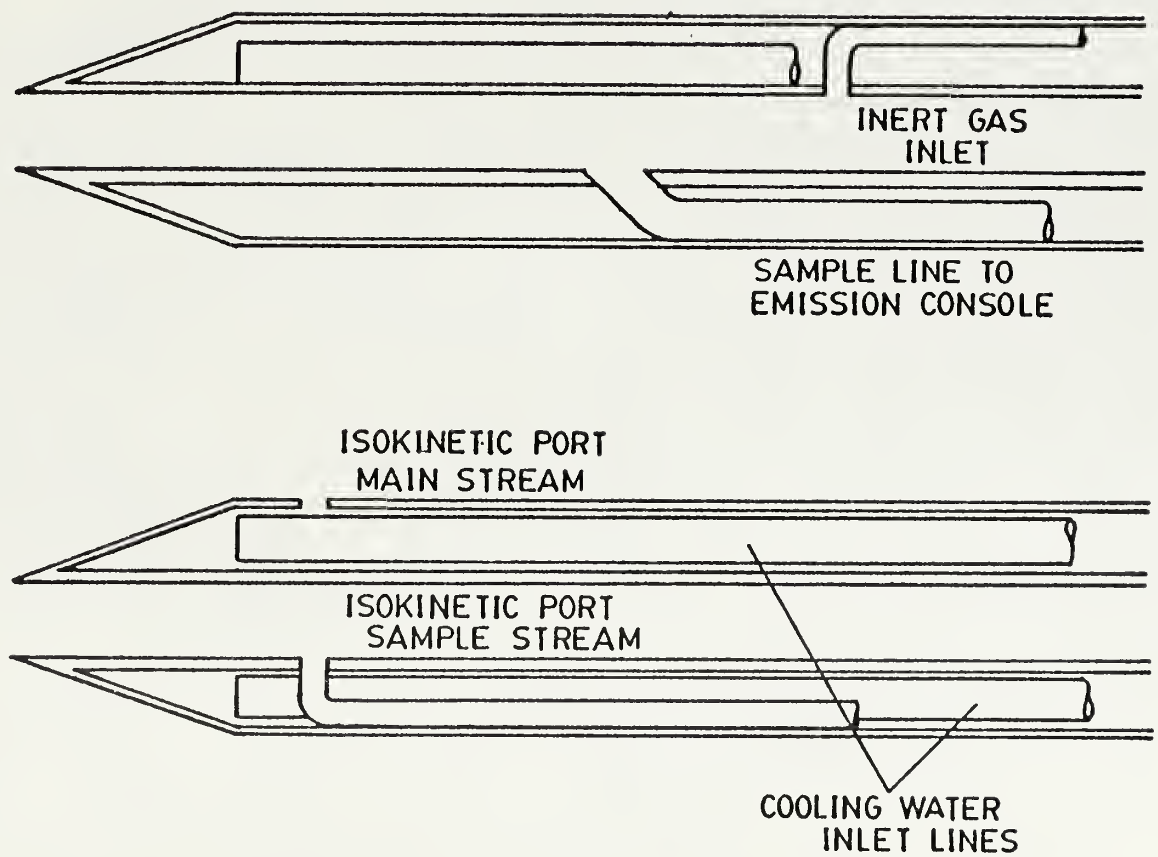

Figure 13. Sampling Probe Diagram.
(Adapted from Figure 2A of Reference 10)

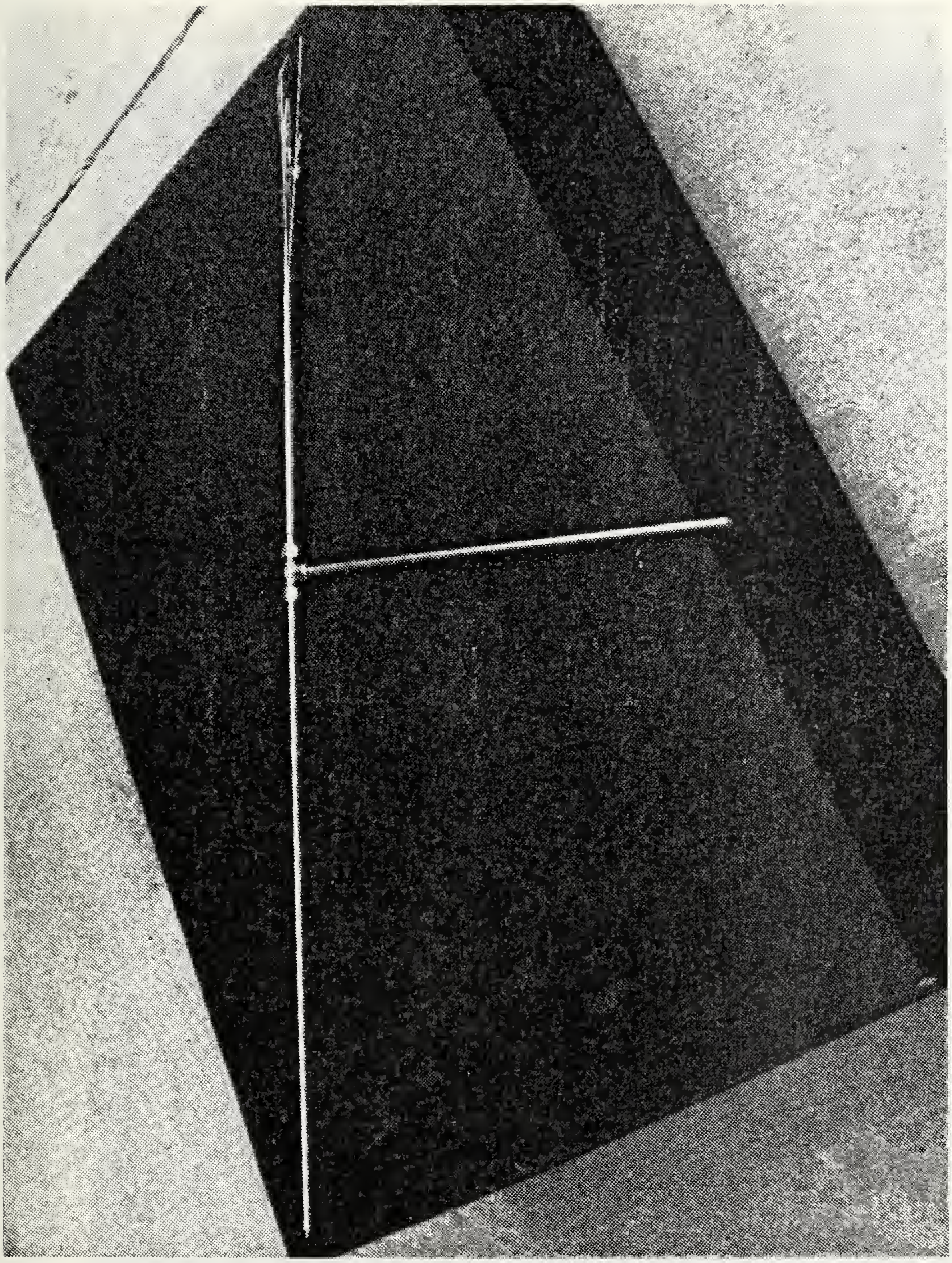

Figure 14. Photograph of Sampling Probe.

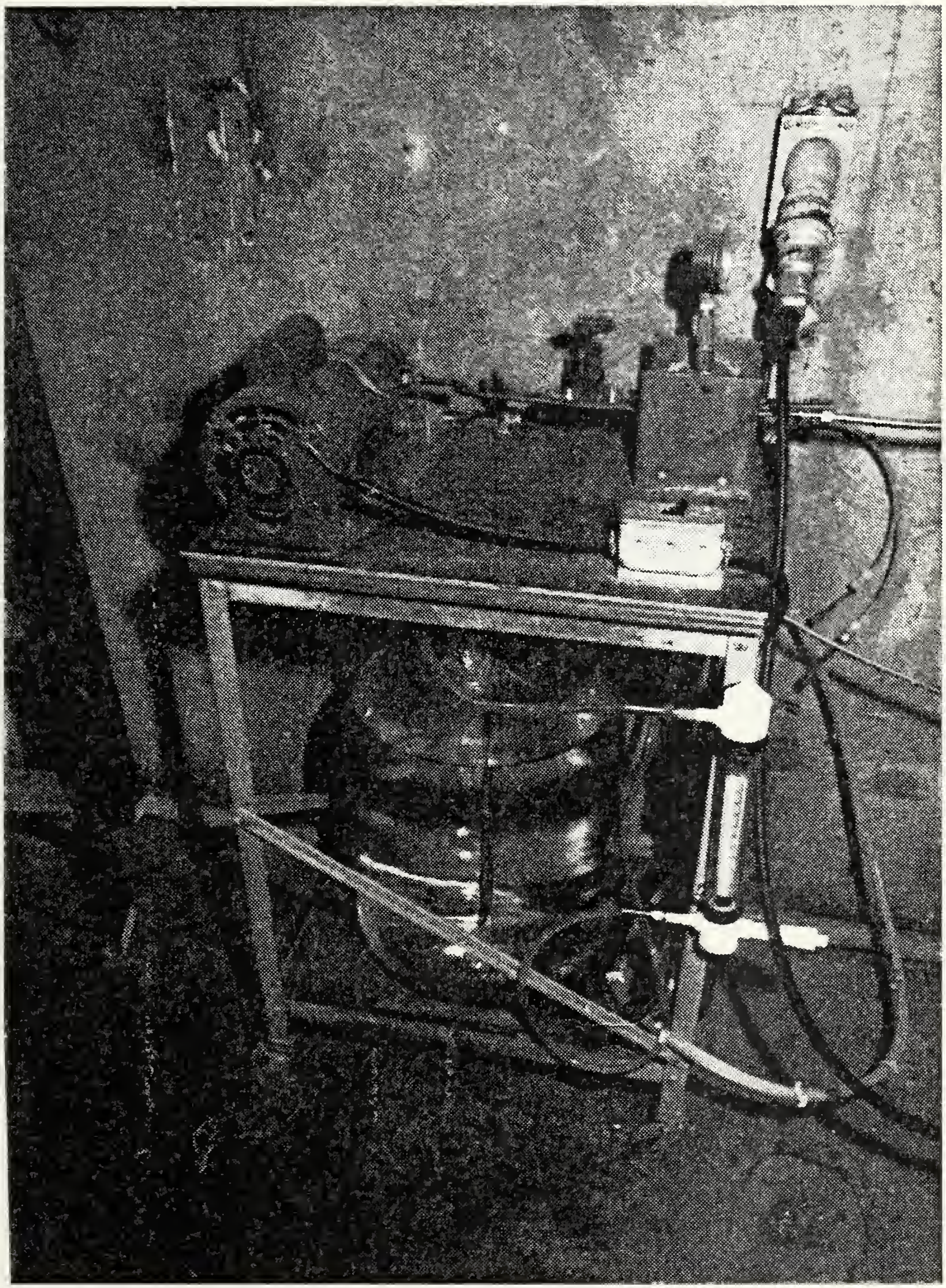

Figure 15. Sampling Probe Water Cooling System.

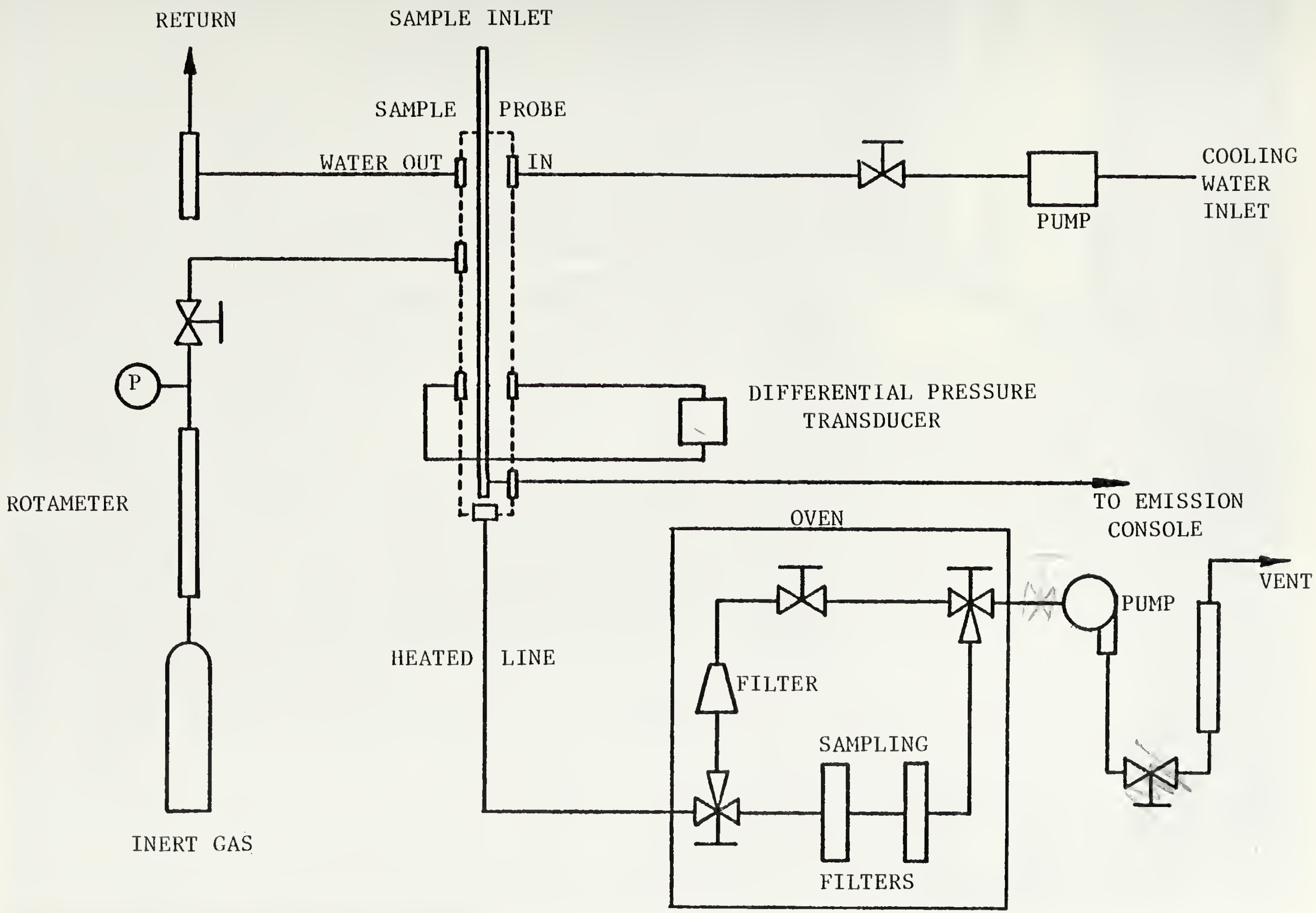

Figure 16. Particulate Collection Apparatus Diagram
(Adapted from Figure 2 of Reference 10)

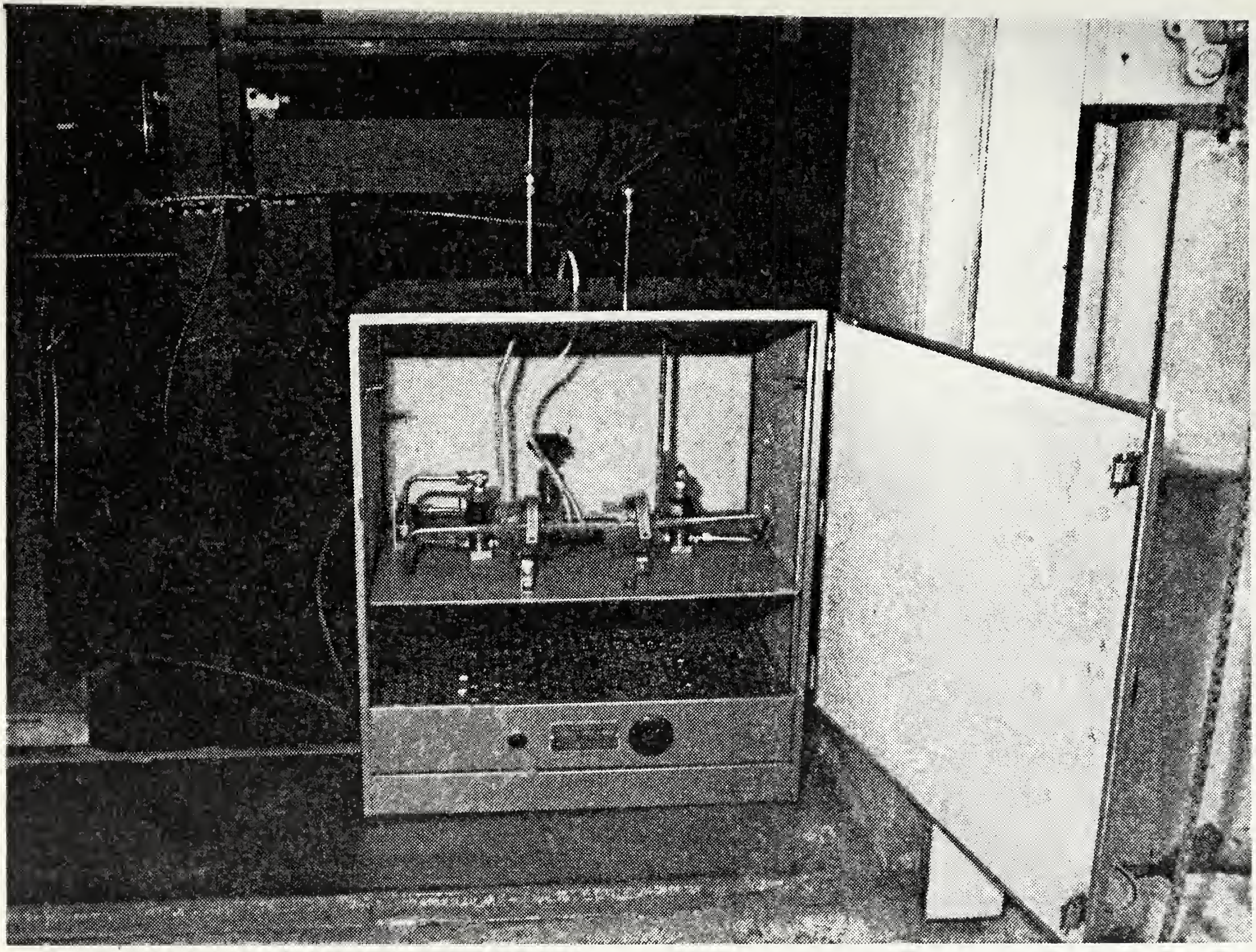

Figure 17. Photograph of Particulate Collection Apparatus and Oven.

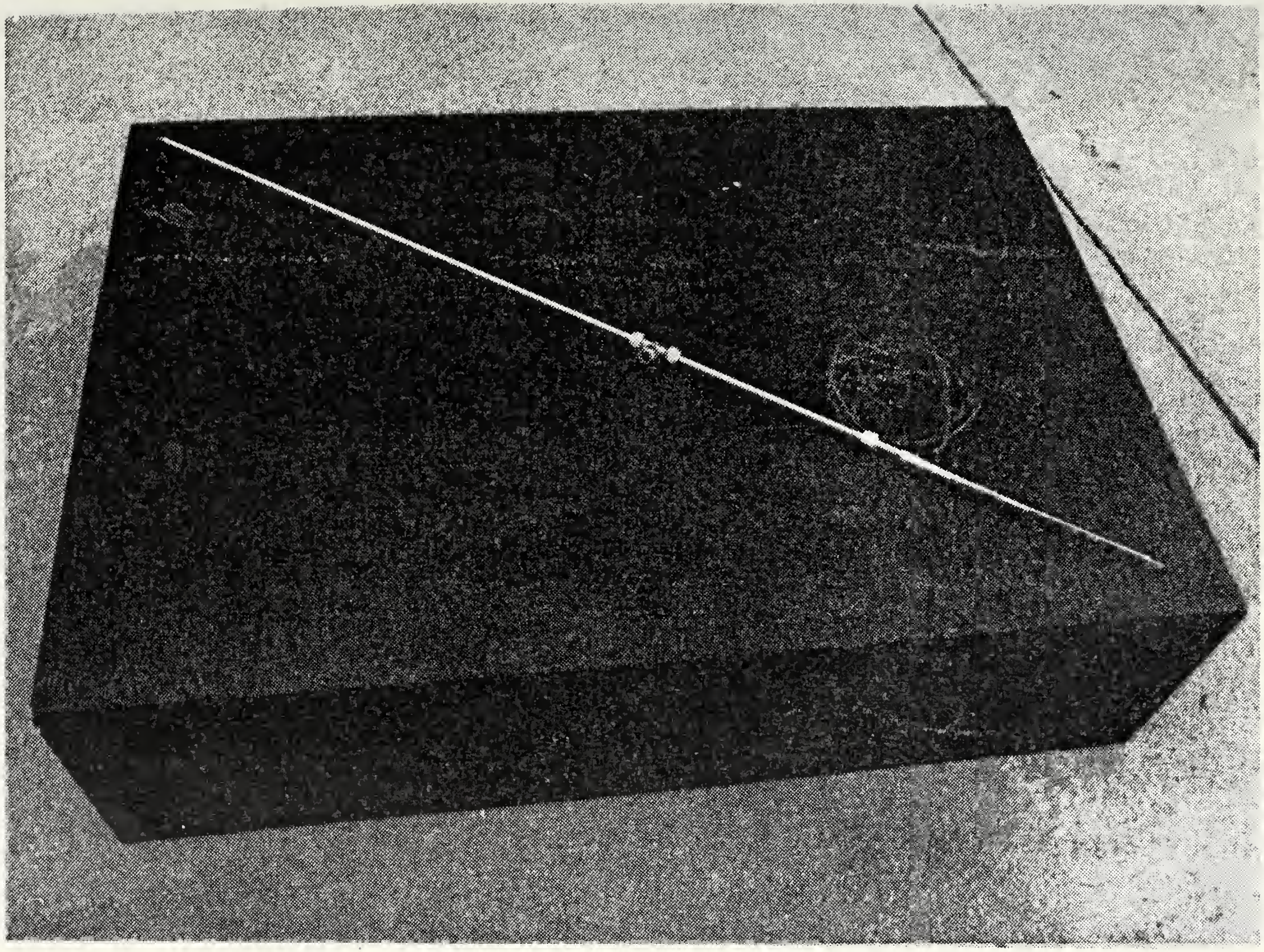

Figure 18. Stagnation Temperature Probe.

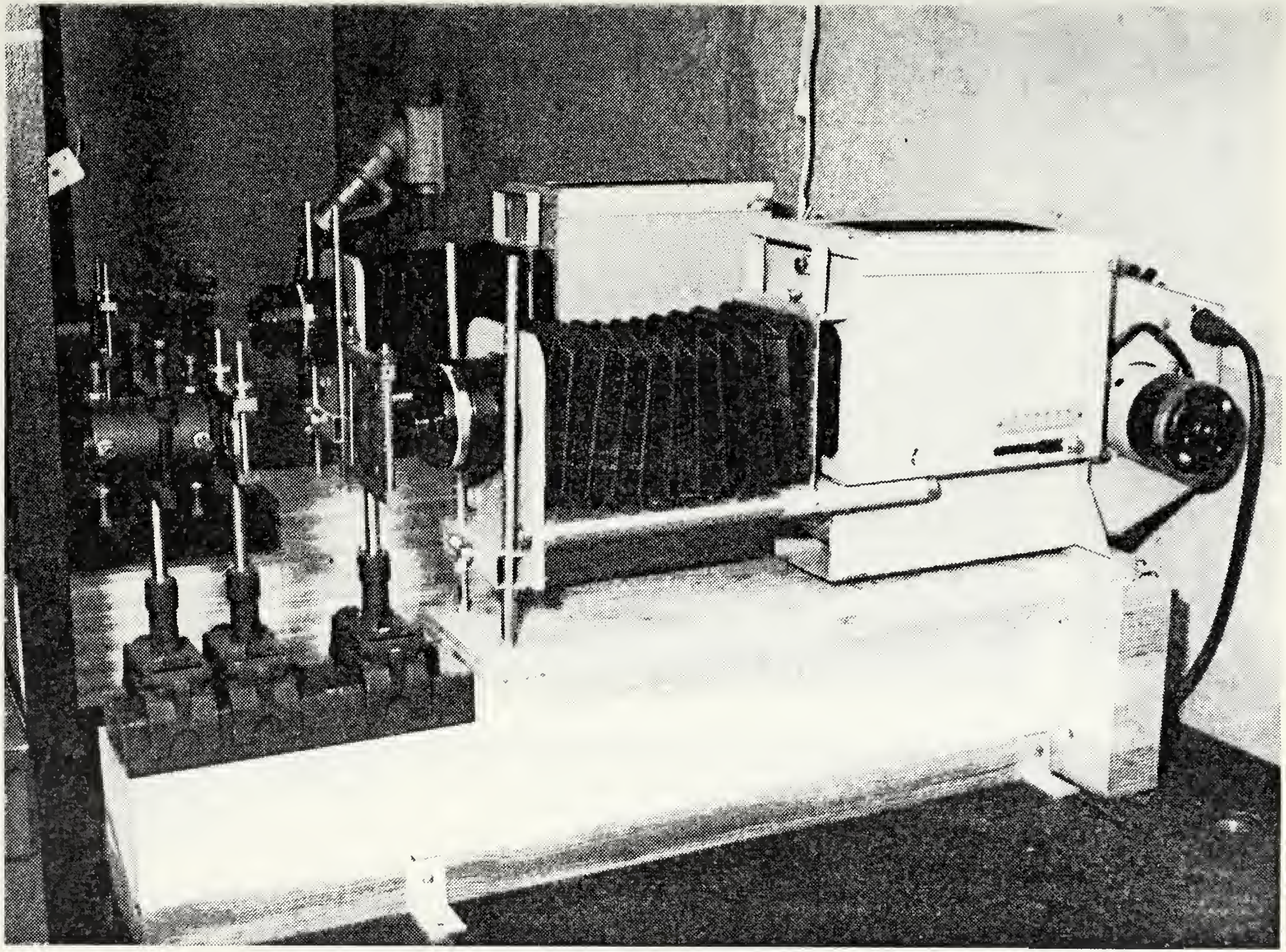

Figure 19. Collimated Light Source.

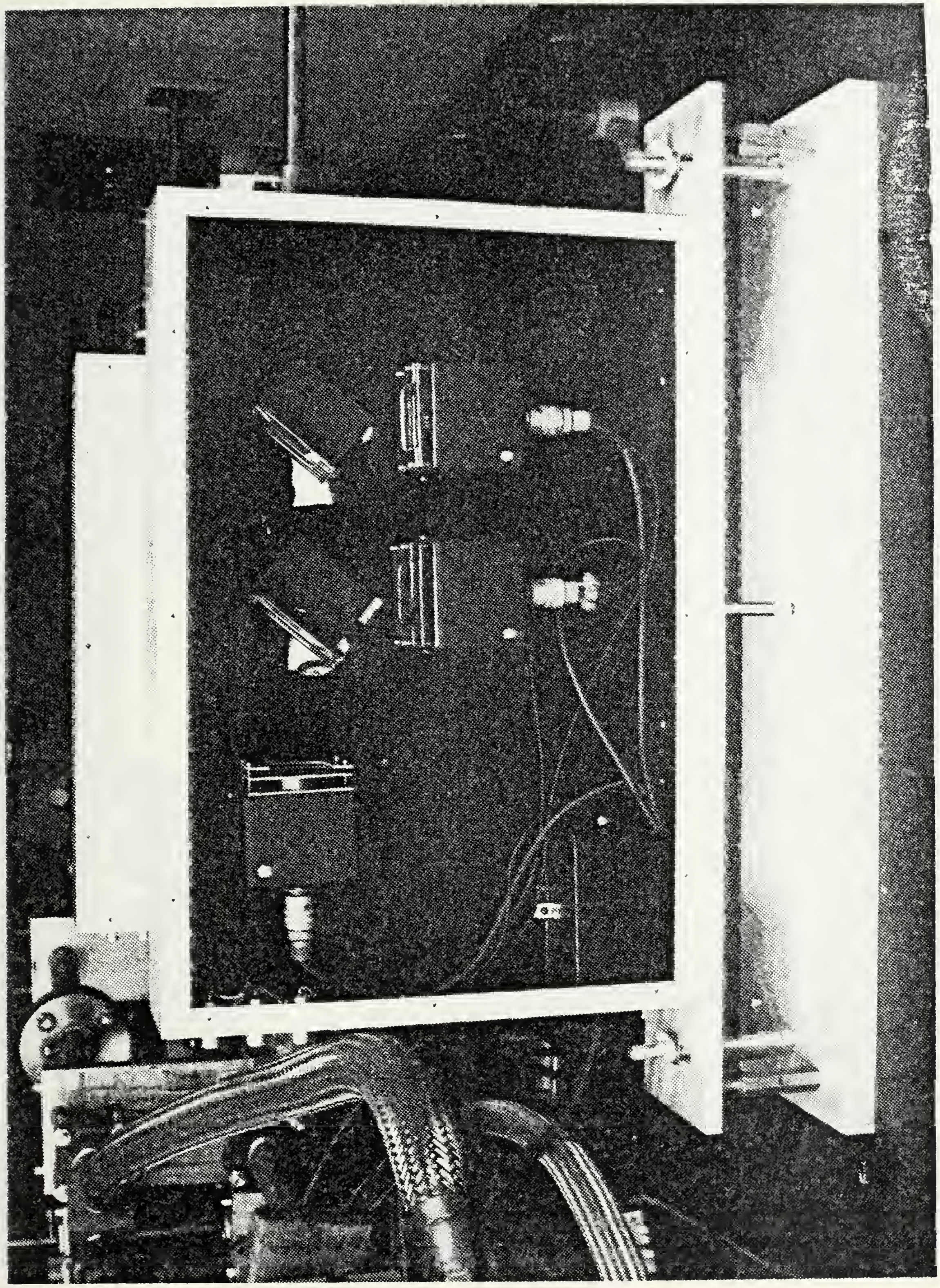

Figure 20. Three Frequency Light Detector.

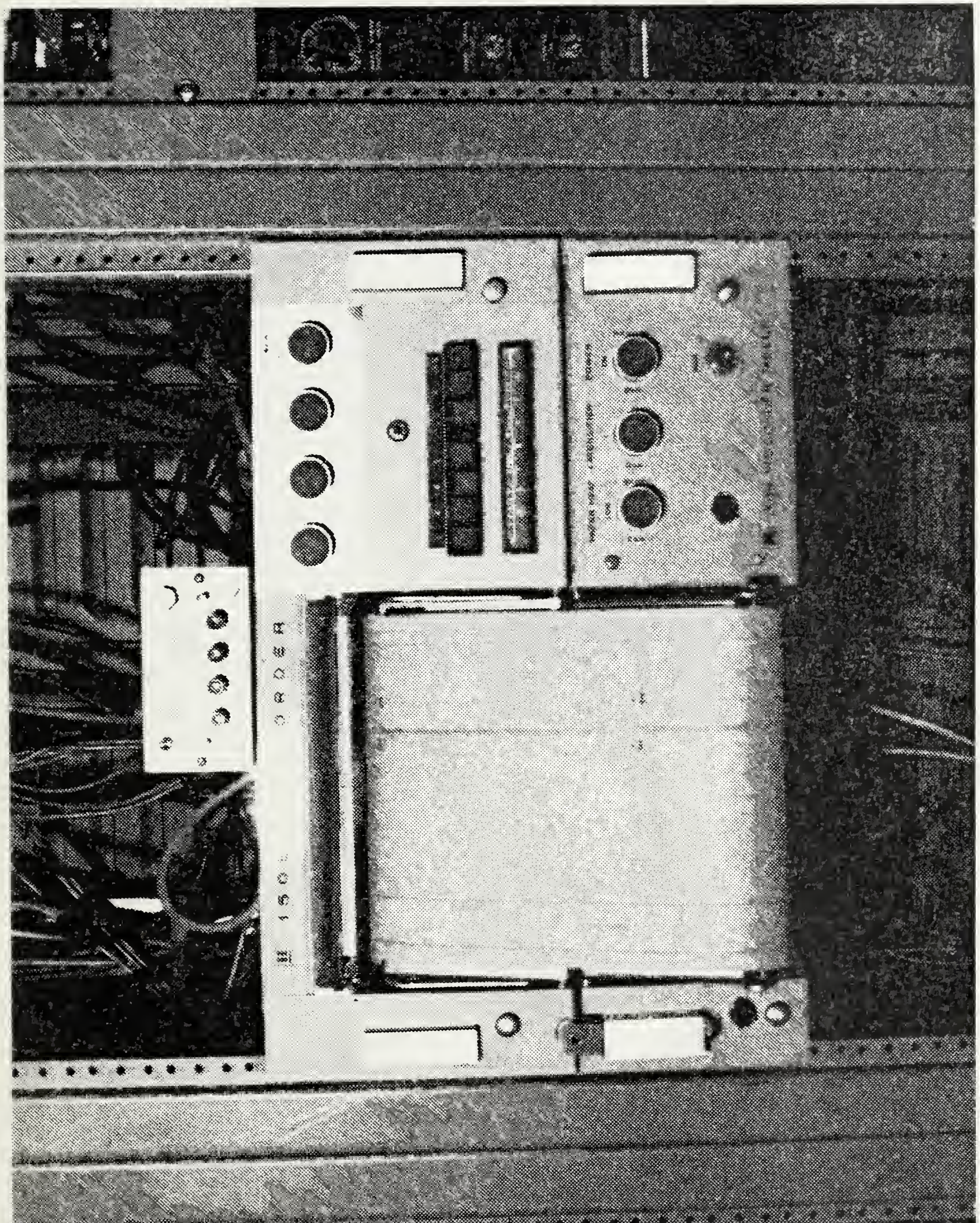

Figure 21. Visicorder.

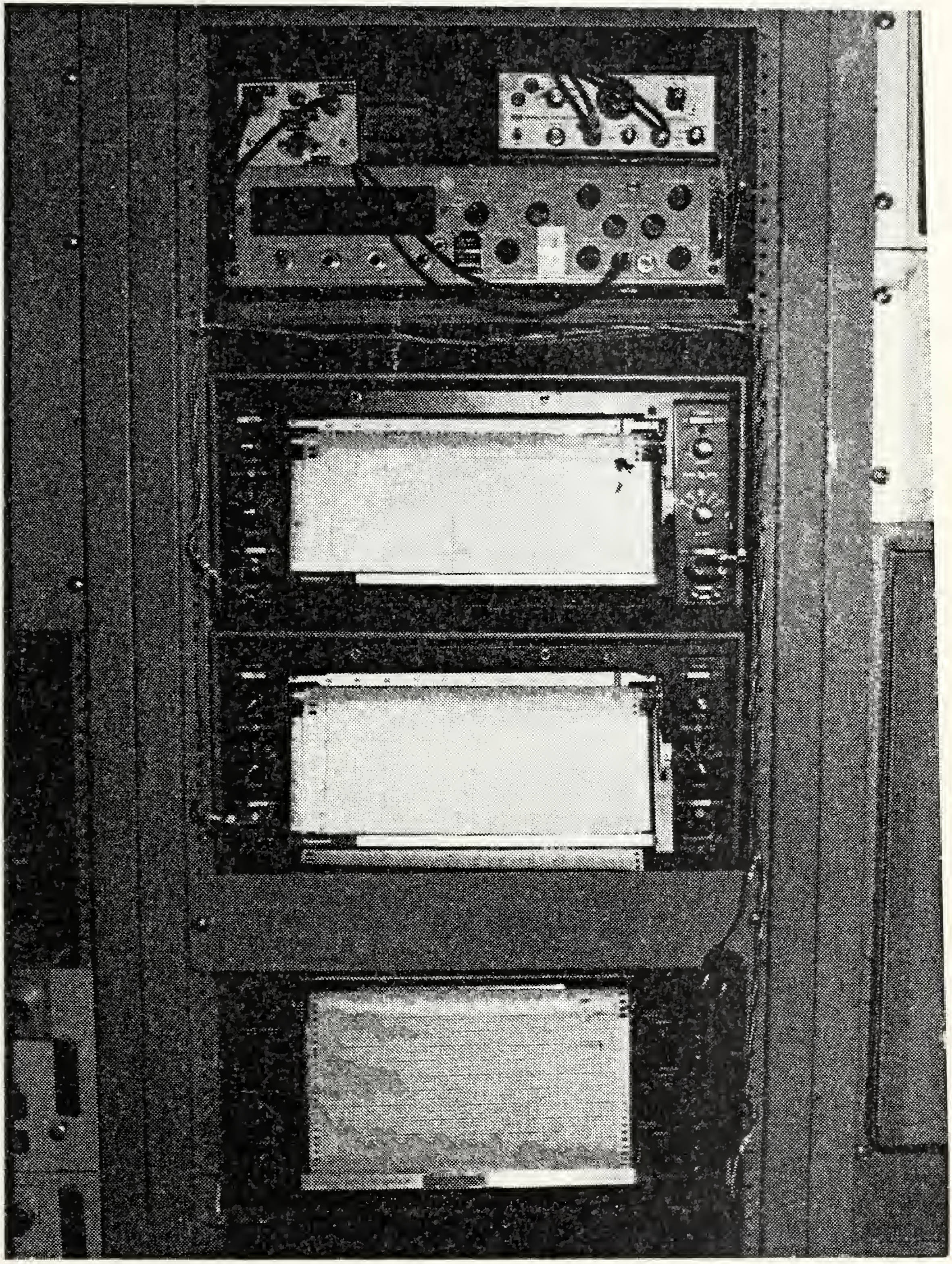

Figure 22. Strip Chart Recorders.

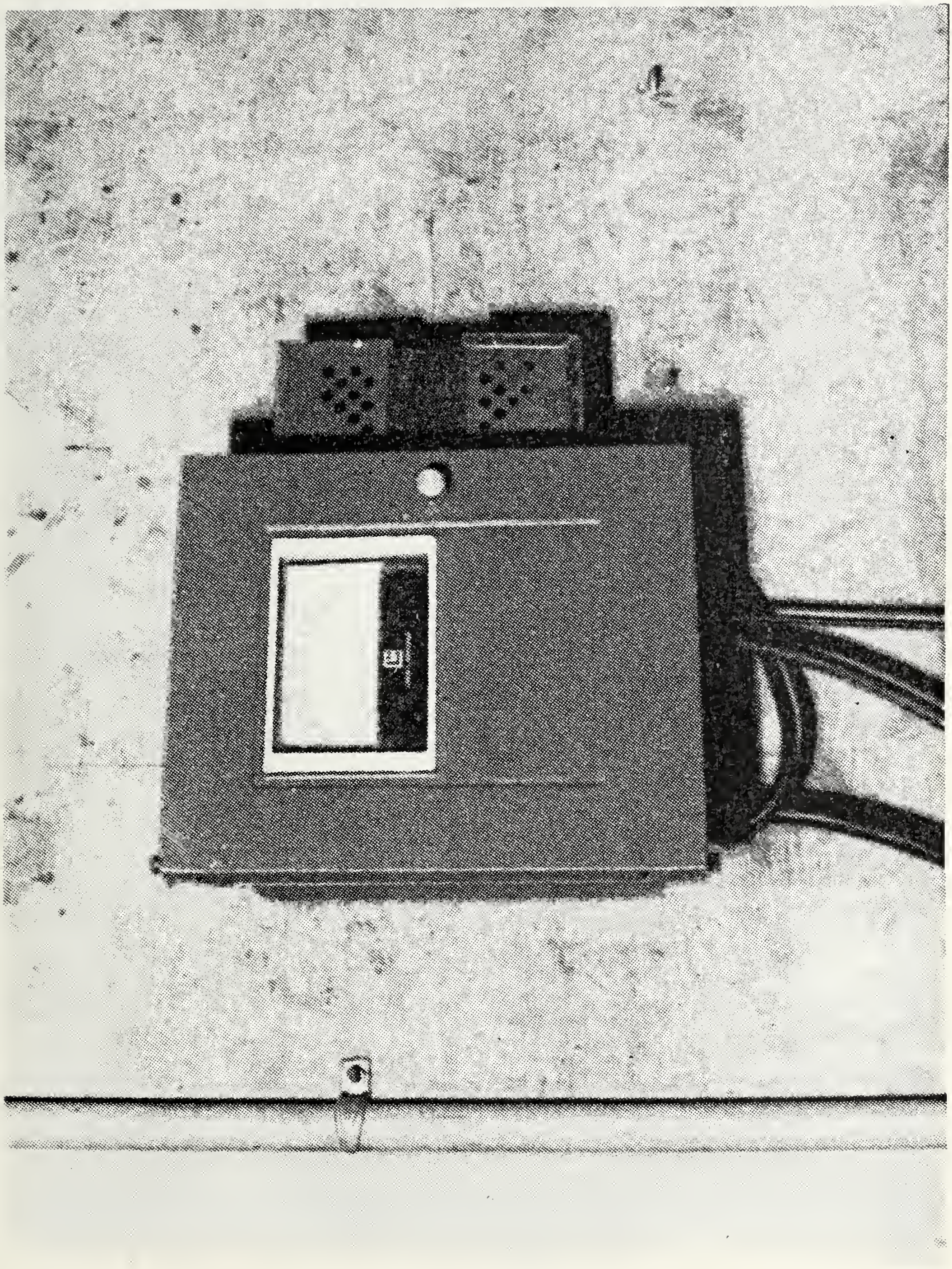

Figure 23. Exhaust Opacity Transmissometer.

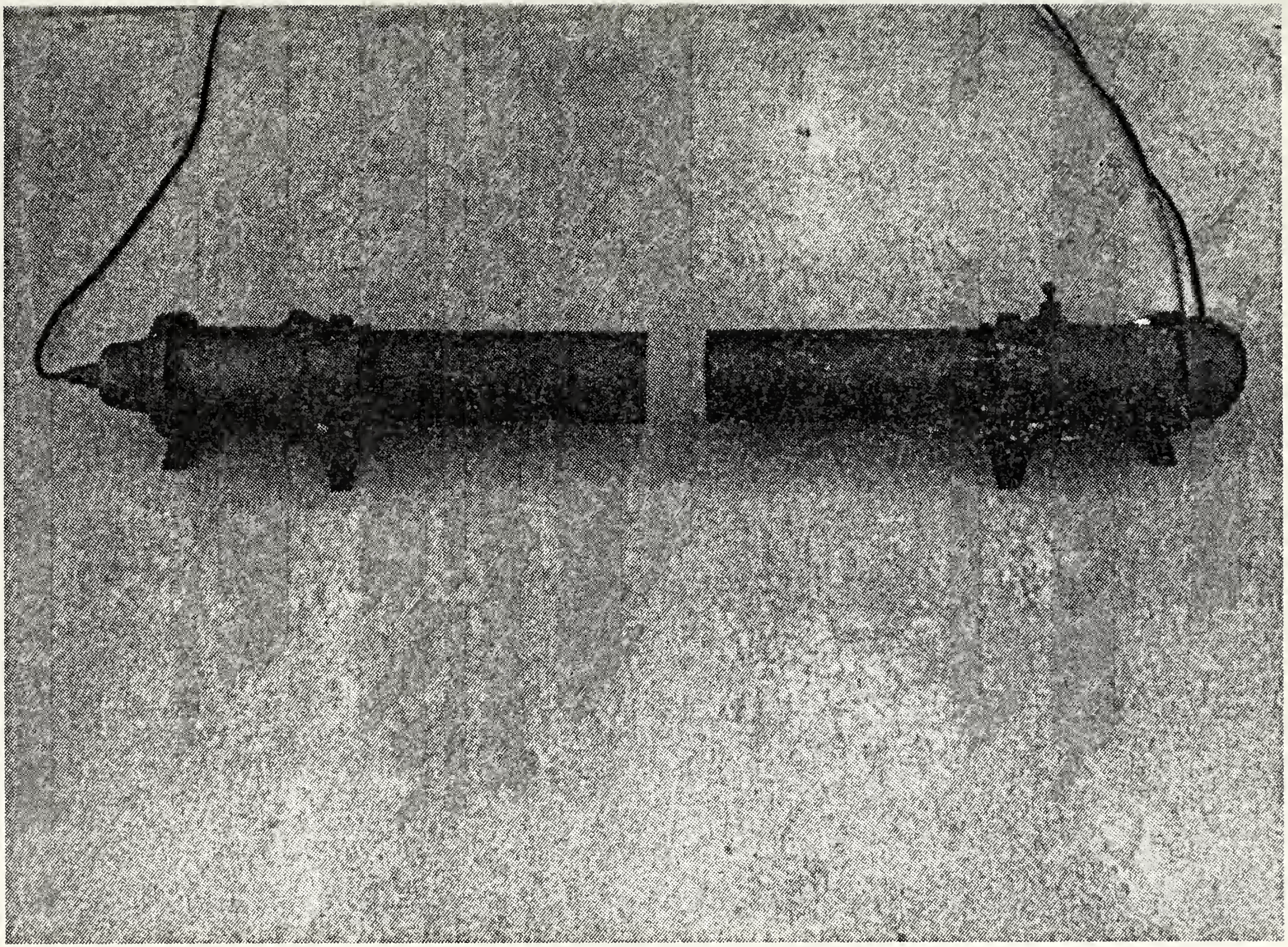

Figure 24. Exhaust Opacity Transmissometer Source and Detector.

TABLE I

LIST OF EXPERIMENTAL FUELS

NAPC FUEL #	DESCRIPTION
1	SUNTECH 1
2	SUNTECH 2
3	SUNTECH 3
4	SUNTECH 4
5	LOW AROMATIC/JP-5
6	FUEL OIL #2
7	HYDROCRACKED GAS OIL/JP-5
8	DIESEL FUEL MARINE/JP-5
9	HIGH AROMATIC/JP-5
10	OIL SHALE/JP-5

TABLE II

TEST DATA AND RESULTS

Run #	Fuel Type	$\dot{m}_a$	$\dot{m}_f$	f	$T_{t_{probe}}$	T_{exit}	T_{air}	P_c	ΔP_{fuel}	P_{air}	Opacity
1	Commercial JP-4	2.52	0.04	0.016	NA	1572	509	98.5	255	432	7.3
2	Commercial JP-4	--	--	--	NA	1492	534	--	--	--	6.0
3	NAPC-9	2.58	0.039	0.015	913.0	1580	492	99.5	255	435	7.0
4	NAPC-9	2.49	0.039	0.016	887.0	1683	492	97.5	255	420	7.0

See Table of Symbols and Abbreviations for explanation of column headings/units.

TABLE III

LIGHT EXTINCTION TEST RESULTS

Within Combustor			Exhaust Exit			
Run #	T_{5145}	T_{6500}	Run #	T_{4500}	T_{6500}	T_{10140}
1	0.40	0.58	1	0.98	0.99	0.96
2	0.41	0.64	2	0.93	0.95	0.94
3	0.40	0.68	3	0.98	0.98	0.99
4	0.37	0.70	4	0.99	0.99	0.98

Note: d_{32}, m, σ data were not obtained.

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